Development of Rations for the Enhanced Survival of Salmon

Annual Report

by

David L. Crawford, Professor
Seafoods Laboratory, Department of Food Science and Technology
Oregon State University

and

Harry Lorz, Program Leader
John Westgate, Project Leader
Jean-Paul Lagasse, Assistant Project Leader
William Fairgrieve, Assistant Project Leader
Oregon Department of Fish and Wildlife

Prepared for

Tom Clune, Special Projects Manager
U. S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife

Contract No. DE-A179-83BP11888
Project 83-363

April 1985

Table of Contents

Introduction

Hydroelectric development coupled with numerous other encroachments on the supply and quality of water has reduced the natural habitat for the spawning and rearing of salmon in the Columbia River system. Artificial production in hatcheries has become a critical link in the restoration of natural stocks of salmon.

Released hatchery salmon must survive predation, be able to acquire sustainable nutrients under natural conditions, possess the vitality to surmount man-made impediments to seaward migration and adapt to a sea water environment. Survival of hatchey salmonids is dependent upon a number of factors. Time of release, natural food abundance, fish size and the health and/or quality of smolts all play synergistic roles.

The nutritional and physical characteristics of ration regimes for hatchery fish plays a major role in determining the effectiveness of hatchery production and the health and/or quality of smolts. Ration regimes containing high quality components in uniform and fine-free pellet forms produce efficient growth response and minimize loss of nutrients maintaining the quality of hatchery water supply. Under such feed regimes, fish are less susceptible to disease and more uniform and desirable fish sizes can be achieved at release time. High quality smolts would help to optimize out-migration survival and successful adaptation to salt water.

The relative success of ration regimes in rearing high quality smolts is dependent upon the quantity and quality of their protein complement. Although adequate levels of energy, essential fatty acids, vitamins and minerals are needed for optimum growth, protein is the major food component for salmonids. Successful fish rations rely on large quantities of fish protein in the form of fish meal as a source of protein. Plant sources of protein (soybean and cottonseed meal) are tolerated to a certain extent based upon growth response, but an excessive replacement of fish protein results in a reduction in feed consumption and growth response parameters (conversion and/or weight gain).

It is believed that salmonids have difficulty in digesting and/or assimilating plant proteins and their presence represents a dietary stress factor. The relative inferiority of plant proteins to those from animal sources other than their obvious poorer amino acid composition may be related to their incompatability to the gastrointestinal system of salmonids. This could be translated into poor digestability and/or the absorption of digested protein moieties that are physiologically unacceptable. Overloading of the relatively limited detoxification system of salmonids would represent a major source of dietary stress.

Commercial fish meals needed for formulating successful ration regimes for hatchery salmon are declining in availability and quantity. This can be directly related to the available supply and cost of raw materials and increased processing costs. The unfavorable position that the aquaculture feed industry commands in the fish meal market exacerbates this situation. The world-wide broiler industry dictates the market price, supply and quality of fish meal.

Industrial fish that in the past formed the raw material base for high quality meal is disappearing because of cost and/or regulation dictating its use for human food. Carcass waste is replacing round fish as a raw material base yielding meals of lower protein and elevated mineral levels. In addition, the potential for protein quality is reduced by higher levels of glanular and skin tissue over muscle tissue in carcass waste.

Overshadowing the raw material supply and compositional problems with fish meal is the biological quality of commercial meals. The majority are produced with efficient direct flame dryers. If driers are precisely operated and raw materials of uniform composition are used, a reasonable quality meal can be produced. However, the degree of variability of raw material now encountered results in a rather high degree of processing damage. Excessive heating damages protein and accentuates lipid-protein interactions reducing biological availability. The basis upon which fish meal is sold does not encourage protein quality. Meals are sold solely on the basis of protein content. Lower protein raw materials such as carcass waste encourages excessive drying to achieve a higher protein content in meal improving their marketability. It is clear that heat damaged proteins are nutritionally inferior and are a source of potential dietary stress to hatchery fish.

Meals produced from whole fish and/or processed and upgraded groundfish carcass waste by low temperature-reduced pressure and/or spray drying procedures would yield protein of optimum quality. These gentle drying processes coupled with the use of fat antioxidants through processing would eliminate heat damage to protein and markedly reduce lipid-protein interactions. Such a ration regime would be more costly, but the improvement in smolt quality could markedly improve survival to adulthood. A few percentage point incease in survival could easily make such a feed regime very cost effective.

It is essential that the true effectiveness of such a ration regime be established. Without a confirmed need and defined value, commercial development required to produce specialized high quality meals for rearing fish will not be forthcoming and the general quality of rations available to rearing fish will continue to decline. This will limit the future ability of artificial propagation to efficiently supplement and enhance natural production.

A ration regime incorporating high quality protein sources would improve the efficiency of hatchery production and should reduce susceptibility of hatchery fish to disease and mortality. Artificial production would be better able to re-establish the vigor of natural runs of salmon in the Columbia River and its tributaries and maintain and improve the genetic integrity of specific stocks. The release of more hardy smolts of more uniform and optimum size should reduce mortality of out-migrants as they encounter prolonged swimming, negotiate passage facilities at dams, undergo the stress of reduced food intake and make the transition to salt water environment. It is believed that survival to adulthood would be increased, enhancing sport, commercial and Indian catches, and increase the number of adults reaching spawning areas supplementing natural production.

Research was designed to establish the influence of feed regimes containing high quality animal protein complements on the efficiency of hatchery production and the return of coho and chinook salmon to the Columbia River system. The key to this feeding regime is the incorporation of low temperature-reduced pressure and/or spray dried fish proteins. It is believed such a feeding regime would yield optimum growth response and minimize nutritional stress yielding hardy high quality smolts of a more uniform and optimum size producing greater survival.

Methods and Materials

The following tasks were required to carry out project objectives: (1) Develop through direct cooperation with a commercial firm a supply of vacuum dried, spray dried and moist concentrated sources of fish proteins for large scale nutritional investigations. (2) Maintain capabilities and facilities for the production of expimental rations required for hatchery scale feeding trials. (3) Develop, modify and evaluate in laboratory scale feeding trials ration formulations for young fry and fingerlings that will provide optimum nutrition for their particular growth requirements. (4) Carry out hatchery scale feeding trials coupled with coded wire tagging survival experiments to establish the relationship between feeding regimes and hatchery production efficiency and fish survival.

High quality sources of fish protein were produced according to specifications by a commercial firm in quantities and within a time frame required to meet project objectives. Protein sources included vacuum dried meals of hatchery salmon carcasses and whole Pacific hake, spray dried bone-free hydrolysates of groundfish carcass waste and whole Pacific hake and bone-free hydrolysed concentrates (50% solids) of groundfish carcass waste and whole Pacific hake.

Vacuum dried meals were produced from hatchery salmon carcass provided by the Oregon Department of Fish and Wildlife and hake were obtained directly from commercial sources. Vacuum drying was carried out with newly constructed equipment located at the Oregon State University Seafoods Laboratory by the cooperating commercial firm under the direction of project personnel. Fish were coarse ground and dried under a vacuum eqivalent to 27-inches of Hg. Product temperature was maintained at about 101-105°F during drying. While the product was hot and moist, the vacuum was allowed to drop for a short period of time to allow product temperature to reach 180°F for 5.0 minutes to affect pasteurization. Product temperatures upon completion of drying were ≤110°F. All vacuum dried meals, if not utilized immediately for ration preparation, were sacked and held frozen.

Both spray dried and moist concentrated (≥50% solids) hydrolysed and bone-free groundfish carcass waste and whole Pacific hake were used as minor protein sources in test rations. This fraction with water performed the same function in the test ration as the wet fish fraction of the Oregon pellet. It enhances acceptance and improves pellet quality. Both products were prepared from bone-free hydrolysates. Instead of spray drying, hydrolysates were concentrated in vacuum with scraped surface heat transfer equipment. The end product was sacked and frozen and held at 0°F. The need for switching from a spray dried product to a moist concentrate was predicated by the loss of spray drying capabilities by the commercial cooperator. Concentrates were prepared at Oregon State University Seafoods Laboratory facilities by the commercial cooperator.

Remaining component required for preparing rations (wheat germ meal, dried whey product, spray dried blood, mineral and vitamin premixes, sodium bentonite, herring oil/antioxidant and choline chloride) were purchased from commercial sources. These commercial sources were either firms that produce moist pelletized ration for hatcheries or provide component to the fish feed industry. All purchased components met specifications for the Oregon pellet.

Rations for laboratory and hatchery scale feeding trials were prepared at the Oregon State University Seafoods Laboratory. Dry ration components (fish meal, dried whey product, wheat germ meal, spray dried blood, trace mineral and vitamin premix, and sodium bentonite) (spray dried hydrolysates of whole fish and groundfish carcass waste are also included if not replaced with moist concentrated counterparts) were milled and usually sacked in 50 lb units. If the dry mix was not used immediately for ration formulation, it was held frozen at ≤0°F. Ration dry mix composition was formulated based upon the composition of the fish meal used in 800-1000 lb batches. The wide variation in the fat and protein content of full fat meals made this necessary to maintain a uniform ration composition. Protein and fat content in the pelletized ration was controlled by varying the fish meal, wheat germ meal and added fish oil fractions of the formulation.

Dry mix was mechanically mixed with remaining "moist" components (herring oil/antioxidant, choline chloride and water or water and moist hydrolysates) in batch sizes approximating 300 lb. Thoroughly mixed components were then mechanically transferred to an extruder where the mix was formed into pellets of required length and diameter. During pelletization, rations were sampled, two replications/batch, to establish the as fed composition of the ration. Pelletized ration was screened sacked in usually 50 lb units (1/32 length-diameter sizes were sacked in 40 lb units) and immediately frozen at -20°F. Ration production capacity approximates 2000 lb/day.

Laboratory scale feeding trials were carried out at the Oregon Department of Fish and Wildlife Clackamas Laboratory. The purpose of these investigations was to acquire information on the relative nutritional value of high quality sources of protein under controlled laboratory conditions. Specific details concerning procedures used for each investigation are outlined in accompanying addendum formal reports.

Hatchery scale feeding trial coupled with coded wire tagging survival experiments to establish the relationship between feeding regimes possessing a high quality protein complement and hatchery production efficiency and fish survival were carried out at Oregon Department of Fish and Wildlife Sandy and Bonneville Hatcheries. Vacuum dried hatchery salmon carcass and hake as major protein sources in test rations were evaluated at Sandy Hatchery with coho (Sandy stock) and vacuum dried salmon at Bonneville Hatchery with fall chinook (tule stock). The hatchery supply of Oregon pellet was utilized as a control for test rations. Duplicate ponds of fish were used for each test and control treatment. Fish were tagged at a rate required to achieve an adequate estimate of relative survival. Detailed information on methods and procedures utilized in hatchery scale feeding trials is outlined in addendum formal reports for each survival evaluation experiment.

Results and Discussion

Laboratory Scale Feeding Trials

Summary: Evaluation of Vacuum Dried Fish Meals, Spray Dried Hydrolysates and Moist Acceptance Enhancing Components in Starter Rations for Salmonids (Addendum A)

Investigations were carried out to evaluate the influence of high quality protein sources on growth and various moist acceptance enhancers on the adaptation of unfed fry to starter rations. Major protein sources tested included vacuum dried hatchery salmon carcasses and whole Pacific hake, steam tube dried salmon hatchery carcasses and spray dried bone-free hydrolysates of salmon hatchery carcasses, hake, groundfish carcass waste and a commercial spray dried fish hydrolysate of unknown origin. Pasteurized krill, beef liver, tuna viscera, squid and shrimp were evaluated as acceptance enhancers. A commercial starter ration (Biodiet; Bioproducts, Inc. Warrenton, OR) was used as reference control. Duplicate lots of spring chinook salmon were supplied test rations for 35 days (a time period customarily involving mash and 1/32-inch pellet sizes).

The growth response of fish revealed the following results: (1) Mash of granular rations customarily included in starter ration regimes for salmonids was sucessfully replaced with a regime of 1/64 and 1/32-inch length-diameter extruded pellets. Experience with the preparation of 1/64-inch pelletized ration showed it to be of doubtful commercial value because of the difficulty in reducing component particle size sufficiently. (2) Protein sources derived from salmon produced the best growth and conversion rates. (3) The performance of vacuum and steam tube dried meals was equivalent, at least for the salmon example evaluated. Vacuum dried hake was inferior to vacuum dried salmon meal. (4) Hydrolysed sources of protein derived from whole fish (salmon and hake) produced growth responses at least equivalent to their intact counterparts. Hydrolysis of hake improved growth response over its intact counterpart. (5) Hydrolysates of groundfish carcass waste and the commercial spray dried fish produced the poorest growth response. (6) Lower body ash levels were observed for fish supplied with rations containing spray dried bone-free hydrolysates as major protein sources. The higher calcium and phosphorous content of rations containing intact meals would appear to be important in the skeletal formation of young fish or produce fish with a greater skeletal mass in relation to body weight. (7) No evidence was observed either of subjective or objective nature to suggest that acceptance enhancers replacing water and in the presence spray dried hydrolysates improved feed recognition or consumption.

<u>Summary: Comparative Evaluation of Vacuum Dried Fish Meal and Spray Dried Hydrolysates to High Quality Commercial Fish Meal as Protein Sources for Fall Chinook Salmon (Addendum B)</u>

Laboratory scale feeding trials were used to define the relative nutritional value of vacuum and spray dried protein sources to high quality commercial meals. High protein herring meal, vacuum dried hatchery salmon carcasses, vacuum dried hake, steam tube dried hatchery salmon carcass, spray dried bone-free hydrolysed hatchery salmon carcasses and spray dried bone-free hydrolysed hake were evaluated in moist and soft-dry test rations. Test rations were fed to duplicate lots of 225 randomly selected fall chinook salmon (tule stock) for 115 days.

Fish response to ration regimes and protein sources yielded the following results and conclusions: (1) Moist rations produced superior growth rates over soft-dry rations through the consumption of more feed and superior feed and protein conversion. Moist ration produced fish of greater mass and length, but condition factors were equal. (2) Vacuum, spray and steam tube dried protein sources of salmon origin produced the best growth and conversion rates. (3) Vacuum dried hake meal produced significantly inferior conversions (dry wt. and protein) to all other sources of protein. (4) The performance of vacuum was only slightly better than steam tube dried salmon meal. (5) High quality commercial herring meal produced growth and conversion rates equivalent to most exerimentally produced vacuum dried meals; poorer than salmon meal, but superior to hake. (6) Hydrolysis of salmon and hake proteins generally improved growth and conversion rates over their intact counterparts. (7) Body compositions (dry wt.) of fish upon termination were equal with regard to protein and fat; body ash contents varied according to protein source. Rations with major protein sources derived from spray dried bone-free hydrolysates possessed lower ash levels and yielded fish with an apparently less developed skeletal mass in relation to flesh.

Hatchery Scale Feeding Trials

Summary: Influence of Ration on the Survival of Coho Salmon. I. 1982 Brood Coho Salmon Rearing Investigation Oregon Department of Fish and Wildlife Sandy Hatchery. (Addendum C).

Duplicate ponds (58,000+ fish/pond) were reared on control Oregon pellet ration and test rations utilizing vacuum dried salmon and hake meals as major protein sources from 27 June 83 to release on 30 April 84. Fish were reared on feeding schedule designed to achieve equal weight at release. Released fish were tagged (injected with coded wire tags and marked with an adipose fin clip between 20 Oct- 11 Nov 83) at rate approximating 45% of the released population.

Coho salmon reared to test the influence of high quality vacuum dried meals on survival yielded the following husbandry results: (1) Control and test rations produced equal mortality ranging from 0.88 to 1.49% of the pond replicate populations. (2) Fish were reared from 4.20-4.40 g to 26.13-26.99 g; feed schedule successfully yielded fish of statistically equal size. (3) Test ration achieved equal weight at release through the consumption of less feed which was converted at a superior rate to that of the control ration. (4) Rations relying on vacuum dried salmon as major protein sources were converted in a manner superior to that relying on vacuum dried hake meal. Better feed conversion by salmon meal rations over the control ration was supported by a better protein conversion. This was not true for hake meal rations. Superior feed conversion of test rations containing hake meal were related to its better fat energy complement over the control ration. (5) At release, the body composition of fish supplied test rations consisted of slightly higher fat levels and lower moisture and protein contents than control fish; ash contents were lower.

Summary: Influence of Ration on the Survival of Fall Chinook Salmon. I. 1983 Brood Fall Chinook Salmon Rearing Investigation; Oregon Department of Fish and Wildlife Bonneville Hatchery (Addendum D)

Duplicate ponds 600,000+ fish (split to 274-277,000+ fish/pond on 24 February 84) were reared on a control Oregon pellet feed regime and a test ration deriving its major protein fraction from vacuum dried salmon meal from 29 December to release on 8 May 84. Rations were supplied to fish on a demand basis. Release fish were tagged (injected with coded wire tags and marked with an adipose fin clip between 17-27 May 84) composed approximately 29% of the fish released (272+ to 275,000+).

Fall chinook salmon reared to establish the influence of high quality sources of fish protein on survival furnished the following husbandry results: (1) Mortality for fish supplied the control ration averaged 5.10% for the period 29 December-23 February 84 and 0.68 from 24 February-8 May 84. Over the same time period fish receiving the test ration showed a 3.18 and 0.53% mortality, respectively. (2) Control fish were reared from an average weight of 0.374 g to 6.042 g (average fork length, 82.5 mm). Equal sized fish, supplied with the ration containing vacuum dried salmon meal, were reared to an average weight of 7.237 g (average fork length, 87.0 mm). (3) The test ration produced larger fish through the consumption of slightly less feed and a superior rate of conversion. The quantity of test ration feed (dry wt.) or protein to produce a unit of body weight or protein gain was 80.2% or 90.6% of the control ration feed system. (4) Fish supplied the test ration possessed body compositions higher in fat and lower in moisture and protein content; higher (112%) blood hematocrits; and a better condition factor through both a greater fork length and weight than control fish upon release.

Hatchery Scale Survival Investigations Underway 31 December 84

Identical survival investigations to those carried out with 1982 brood coho and 1983 brood fall chinook salmon have been initiated at Sandy and Bonneville Hatcheries with 1983 brood coho and 1984 brood fall chinook (tule stock), respectively. Coded wire tagged fish from both of these hatcheries are due to be released in May 85.

ADDENDUM A

DEVELOPMENT OF RATIONS FOR THE ENHANCED SURVIVAL OF SALMON

Bonneville Power Administration Project 83-363

Evaluation of Vacuum Dried Fish Meals, Spray Dried Hydrolysates and Moist Acceptance Enhancing Components in Starter Rations for Salmonids

Introduction

The success of hatchery production of salmonids is greatly enhanced by how well and early unfed fry begin consuming ration and growing. This is dependent to a considerable extent on how well starter rations are "accepted". Factors determining the acceptability of starter rations are not well defined, but it is believed that particle size, density, and composition play important roles. Inclusion of moist products derived from crustacea, mollusc, the viscera of certain fin fishes and the liver of beef are believed to have favorable effects on acceptance.

This investigation was designed to evaluate the influence of high quality protein sources and various moist enhancers on the acceptance of starter rations and growth of unfed fry. Vacuum dried hatchery salmon carcass and hake and steam tube dried salmon carcass were included in the investigation. Spray dried hydrolysates of salmon carcasses, hake, groundfish carcass waste and a commercial spray dried fish hydrolysate of unknown species origin were also tested. Pasteurized krill, beef liver, tuna viscera, squid and shrimp were evaluated for their acceptance enhancing capabilities.

Methods

Experimental Conditions

Aproximately 18,000 unfed spring chinook alevins were obtained from the Clackamas fish hatchery, near Estacada, OR and transferred to the nutrition laboratory at Clackamas, OR in late December of 1983. The young fish were maintained in unrecirculated spring water at a temperature of 12°C and a dissolved oxygen concentration of about 8 ppm until all fish made at least momentary excursions from the tank bottom. At that time, 26 samples of 260.0 g each were transferred to individual 0.92 m diameter x 0.72 m depth cylindrical fiberglass tanks. Water volume was adjusted to 150.0 l by means of a centrally located standpipe drain, and unrecirculated spring water (12°C) supplied to each at a rate of 8.0 l per minute. Overhead fluorescent lights provided a diurnal light:dark cycle of 9:15 hours.

Experimental Rations

Biodiet (Bioproducts, Inc., Warrenton, OR), a high quality moist starter ration, served as a reference control. Formulations of experimental rations (12) coded according to the sources of protein [vacuum dried salmon meal(VSM), vacuum dried hake meal (VHKM), steam tube dried salmon meal (STSM), spray dried hydrolysed salmon (SDHYS), spray dried hydrolysed hake (SDHYHK), spray dried hydrolysed carcass waste (SDHYCW), spray dried fish (commercial) (SDHYF)] and acceptance enhancers (krill, beef liver, tuna viscera, squid and shrimp) with compositions of major ration protein sources and pelletized rations are listed in Appendix I. Biodiet was supplied as No. 1 and 2 starter granules and as 1.0 mm grower pellets. Experimental rations were extruded into 1/64-inch pellets (replacing the starter mash customarily used) and 1/32-inch pellets. All rations were stored in sealed plastic containers at -12°C until fed.

Feed Presentation

Alevins were randomly assigned among the ration treatments, each treatment in duplicate. Initial presentation of feed began after most fish had achieved neutral buoyancy and the externally visible yolk sac had disappeared. Alevins were fed at a rate of 4.88% (dry matter) of the initial tank biomass per day for 10 days to ensure equal opportunity to begin feeding, then on a to-appetite basis during the remainder of the 35 day trial. All fish were fed by hand four to seven times each day, except on sampling days, when rations were withheld. Fecal material and uneaten feed were siphoned from the tanks, mortalities collected and weighed, and feed consumption data recorded daily. Rations were stored between feedings in covered plastic containers at about 8°C.

The influence of particle size on consumption of pelleted experimental rations was controlled by feeding only 1/32-inch pellets until a mean fish weight of 0.56 g was achieved and only 1/32-inch pellets thereafter. Alevins fed the reference control ration received No.2 granules for the first 10 days of the trial, then No.3 granules until they were at least 0.56 g, and finally 1.0 mm pellets.

Sampling

Sampling to assess changes in alevin weight and fork length was conducted immediately prior to initial presentation of feed and after 11 and 35 growing days. At those times, the biomass of fish in each tank was first determined, then one or more samples of at least 40 alevins collected from each and weighed to the nearest 0.1 g. Sampled alevins were anesthetized with triciane methane sulfonate, measured to the nearest 1.0 mm fork length with vernier calipers, and returned to the appropriate tanks. Changes in pellet size were based on weight data obtained from small samples collected after 18 and 23 growing days. Growth response data by replicate lot are listed in Appendix II.

Upon termination of the feeding trial, random samples of 80 to 90 fish were collected from each treatment replicate. Samples were subjected to analysis for proximate composition; results by replicate lot are listed in Appendix III.

Data Analysis

At termination, overall rates of growth in length ($l_1 - l_0$ /day) and weight (100 x ln wt_1 - ln wt_0 /days) were calculated. Feed/gain (dry wt.) (g of dry feed offered/ g wet wt. gain) and protein efficiency ratios (PER) (g wet wt. gain/g protein offered) were estimated for periods of to-appetite feeding when care was taken to avoid feed wastage. Analysis of variance was applied to growth, feed utilization and flesh composition data. Duncan's multiple range test was employed to separate treatment means at the 0.05 significance level.

Results and Discussion

Mash or granular diets customarily included in starting ration regimes for salmonids were successfully replaced with a regime of extruded 1/64 and 1/32-inch pellet forms. First feeding fish had no difficulty in consuming the pelletized ration and fish response was equal to the granular commercial ration. Rations were equally easy to handle, although pelletized rations had a tendency to stick together once thawed. A slight shaking in a covered container was all that was required for separation.

As an option for the preparation of starter rations extrusion has advantages over crumbling larger pellet sizes coupled with screening. This is particularly true if spray dried bone-free products were available for formulation. However, maintenance of small enough particle sizes was very difficult to achieve even in a laboratory situation. On a commercial basis, the experience gained in this investigation showed this option to have a low level of feasibility.

Prior to presentation of feed, no significant numbers of fish were lost. Fish appeared to be in good health with no gross signs of infectious or noninfectious disease processes observed. Mortality rose to about 1% per day (8-10 fish/replicate/day) shortly after initial feeding. Mortality, however, declined rapidly without treatment to 1 or 2 fish per replicate on the 17th day of the trial. Only an occasional fish was lost thereafter. The etiologic agent(s) were tentatively identified as those of the *Aeromonas hydrophyla* complex. Alevins reared at the source hatchery were also observed to experience this problem.

Rations produced growth rates that varied in a significant (P≥.001) manner (Table 1). Rations deriving their major protein complements from SDHYCW and the commercially produced SDHYF yielded rates of weight and fork length gain inferior (P=.05) to the reference control. The rate of weight gain for fish supplied the ration containing VHKM was superior to SDHYCW and SDHYF, but inferior to VSM and SDHYS with beef liver (P=.05). It was equal (P=.05) to all other protein sources. The reference control and test rations containing the protein sources VSM, STSM, SHYHK, SDHYS and SDHYS with all of the tested acceptance enhancers produced equal (P=.05) rates of weight gain. Protein sources yielded growth rates as measured by fork length increase similar to that for weight. Acceptance enhancing components in the ration containing SDHYS as the major protein source did not (P=.05) effect growth rate (weight and length) in direct comparison to water. The most rapid growth was produced by protein sources originating from salmon; the steam tube dried salmon product yielded growth equal to vacuum and spray dried.

Table 1. Mean fish size and growth rate

Major protein source "moist" component	Fish weight(g) Initial	Final	Fish length (mm) Initial	Final	Specific growth rate (%/day)[1,2]	Rate of length increase (mm/day)[1,3]
(Reference control)[4]	0.32	1.15	34.7	50.1	3.66^{ab}	0.43^{b}
VSM[5] - water	0.30	1.29	34.8	50.5	4.13^{a}	0.44^{ab}
STSM[6] - water	0.31	1.30	34.5	51.7	4.10^{ab}	0.48^{a}
VHKM[7] - water	0.31	1.10	34.4	48.2	3.61^{b}	0.38^{c}
SDHYHK[8] - water	0.31	1.17	34.5	50.0	3.83^{ab}	0.43^{b}
SDHYCW[9] - water	0.32	0.75	35.0	42.7	2.44^{c}	0.21^{e}
SDHYF[10] - water	0.31	0.84	34.8	45.2	2.75^{c}	0.29^{d}
SDHYS[11] - water	0.31	1.24	34.6	50.4	3.94^{ab}	0.44^{ab}
SDHYS - krill	0.31	1.18	34.4	50.5	3.80^{ab}	0.45^{ab}
SDHYS - beef liver	0.31	1.31	34.9	51.3	4.12^{a}	0.45^{ab}
SDHYS - tuna viscera	0.32	1.21	34.3	49.8	3.81^{ab}	0.43^{b}
SDHYS - squid	0.31	1.20	34.6	49.9	3.97^{ab}	0.43^{b}
SDHYS - shrimp	0.32	1.19	34.6	50.5	3.78^{ab}	0.44^{ab}
F-value					20.536	29.705
Significance					P≥.001	P≥.001

[1]Based upon ad lib. feeding from 0 through 35 days [2]100 (ln final wt. - ln initial wt.)/days [3]Final length - initial length/days [4]Biodiet Starter Ration; Bioproducts, Inc., Warrenton, OR [5]Vacuum dried salmon hatchery carcasses [6]Commercial steam tube dried salmon hatchery carcasses [7]Vacuum dried Pacific hake [8]Spray dried hydrolysed Pacific hake [9]Spray dried hydrolysed groundfish carcass waste [10]Commercial spray dried fish [11]Spray dried hydrolysed salmon hatchery carcasses.

Mean values in a column with same exponent letter did not vary significantly (P=.05)

The palatability of all rations was very good. No evidence (P=.05) was observed either of a subjective nature or based upon feed consumption between 11 and 35 days when consumption was measured in an accurate manner to suggest that acceptance enhancers replacing water improved palatability (Table 2). Feed recognition and consumption was observed by the second day of the trial, active feeding by the sixth day, and very good response by the tenth day regardless of ration treatment. Rations containing hydrolysed spray dried protein sources consumed quantities of feed equal to the reference control, but less than rations containing vacuum and steam tube dried intact protein sources (P=.05). This was a direct response to the more nutrient dense characteristics of the rations containing hydrolysed spray dried protein sources. It is clear that moist material that have been preconceived to provide improved acceptance do not in rations containing high quality protein products and in particular hydrolysed and spray dried products.

Feed conversion (dry wt.) for the reference control and test rations containing the protein sources VSM, STSM, SDHYHK, SDHYS and SDHYS containing acceptance enhancers did not vary significantly (P=.05) (Table 2). The conversion (dry wt.) of rations containing the protein sources VHKM, SDHYF and SDHYCW produced inferior (P=.05) conversions in the listed order. Hydrolysis of hake protein significantly (P=.05) improved feed (dry wt.) conversion. The efficiency of the protein fraction of rations varied significantly (P≥.001) (Table 2), but revealed generally the same results as those observed for feed (dry wt.)/gain. The only exception was related to the observation that SDHYS with krill produced a significantly (P=.05) poorer protein efficiency ration than SDHYS with beef liver. Proteins of vacuum, steam tube and spray dried salmon were converted at an equal rate.

Table 2. Mean feed consumption and conversion

Major protein source "moist" component	Feed (g dry wt.) 0-10 days	Feed (g dry wt.) 11-35 days	Feed(dry wt.)/gain[1]	Protein efficiency[1,2]
(Reference control)[3]	127.7	319.0^{bc}	0.68^{a}	2.44^{bcd}
VSM[4] - water	123.0	339.8^{ab}	0.66^{ab}	2.68^{abc}
STSM[5] - water	124.0	337.1^{ab}	0.64^{ab}	2.73^{ab}
VHKM[6] - water	125.4	351.3^{a}	0.81^{c}	2.27^{d}
SDHYHK[7] - water	125.0	307.0^{cd}	0.65^{ab}	2.37^{c}
SDHYCW[8] - water	128.4	296.6^{cd}	1.10^{e}	1.59^{f}
SDHYF[9] - water	126.9	283.3^{d}	0.93^{d}	1.70^{e}
SDHYS[10] - water	127.4	299.4^{cd}	0.62^{ab}	2.49^{abcd}
SDHYS - krill	126.2	297.5^{cd}	0.66^{ab}	2.35^{d}
SDHYS - beef liver	126.3	298.7^{cd}	0.56^{b}	2.78^{a}
SDHYS - tuna viscera	127.4	297.9^{cd}	0.62^{ab}	2.47^{abcd}
SDHYS - squid	125.6	291.2^{d}	0.61^{ab}	2.50^{abcd}
SDHYS - shrimp	126.3	291.6^{d}	0.61^{ab}	2.42^{bcd}
F-value		6.089	19.735	13.941
Significance		P≥.005	P≥.001	P≥.001

[1]Based upon *ad lib.* feeding from the eleventh through the thirty-fifth day [2]Wet weight gain (g)/protein offered (g) [3]Biodiet Starter Ration; Bioproducts, Inc., Warrenton, OR. [4]Vacuum dried salmon hatchery carcasses [5]Commercial steam tube dried salmon hatchery carcasses [6]Vacuum dried Pacific hake [7]Spray dried hydrolysed Pacific hake [8]Spray dried hydrolysed ground fish carcass waste [9]Commemrcial spray dried fish [10]Spray dried hydrolysed salmon hatchery carcasses

Mean values in a column with same exponent letter did not vary significantly (P=.05)

Ration composition significantly influenced the moisture (P≥.001) and dry weight ash (P≥.001), fat (P≥.001) and protein (P≥.01) content of fish (Table 3). The body ash content of fish supplied rations with spray dried protein sources was lower (P=.05) than rations containing intact meals as their major source of protein. Generally this lower ash content was accompanied by higher fat content and lower body moisture and protein levels. Composition variation dependent upon the species source of the major protein source appeared to be minimal. Differences that did exist were related to body fat content and its usual relationship to moisture and protein levels. Lower body ash contents reflected a considerably less developed skeletal structure per body mass for fish supplied spray dried protein sources. Bone removed from hydrolysates prior to spray drying reduced ration ash content from 18-19% (dry wt.) for rations containing intact protein sources to 7-8%. The higher calcium and phosphorous content of intact protein meals would appear to be important in the skeletal formation of young fish or produces fish with a greated skeletal mass in relation to body weight.

Table 3. Mean body composition

Major protein source - "moist" component	Moisture (%)	Percent dry weight		
		Ash	Fat	Protein
(Reference control)[1]	78.62^{b}	9.59^{a}	27.02^{d}	65.72^{bc}
VSM[2]-water	78.56^{b}	9.49^{a}	27.87^{cd}	66.12^{abc}
STSM[3] - water	78.11^{b}	9.09^{b}	29.37^{abcd}	64.09^{cd}
VHKM[4] - water	78.52^{b}	9.43^{a}	27.14^{d}	65.79^{abc}
SDHYHK[5] - water	78.03^{b}	7.78^{cd}	30.57^{abcd}	64.49^{cd}
SDHYCW[6] - water	79.82^{a}	7.93^{c}	28.09^{bcd}	68.10^{a}
SDHYF[7] - water	79.59^{a}	7.61^{cde}	28.64^{bcd}	67.60^{ab}
SDHYS[8] - water	77.45^{c}	7.38^{e}	32.79^{ab}	63.20^{d}
SDHYS - krill	78.00^{bc}	7.41^{de}	33.88^{a}	64.97^{cd}
SDHYS - beef liver	77.64^{c}	7.53^{de}	32.48^{ab}	64.17^{cd}
SDHYS - tuna viscera	77.77^{c}	7.67^{cde}	31.98^{abc}	64.24^{cd}
SDHYS - squid	78.03^{b}	7.51^{de}	32.48^{ab}	64.83^{cd}
SDHYS - shrimp	77.82^{c}	7.52^{de}	32.25^{abc}	64.28^{cd}
F-value	12.947	79.762	28.365	4.312
Significance	$P \geq .001$	$P \geq .001$	$P \geq .001$	$P \geq .01$

[1]Biodiet Starter Ration; Bioproducts, Inc., Warrenton, OR [2]Vacuum dried salmon hatchery carcasses [3]Commercial steam tube dried salmon hatchery carcasses [4]Vacuum dried Pacific hake [5]Spray dried hydrolysed Pacific hake [6]Spray dried hydrolysed groundfish carcass waste [7]Commercial spray dried fish [8]Spray dried hydrolysed salmon carcasses

Mean values in a column with same exponent letter did not vary significantly (P=.05).

APPENDIX I
Ration Description, Formulation and Composition

Ration Description:

Ration code
- 17 Biodiet Starter Ration (BSR)(Bioproducts, Inc., Warrenton, OR)
- 18 Vacuum dried salmon hatchery carcasses (VSM) - water
- 19 Commercial steam tube dried salmon carcasses (STSM) - water
- 20 Vacuum dried Pacific hake (VHKM) - water
- 21 Spray dried hydrolysed hake (SDHYHK) - water
- 22 Spray dried hydrolysed groundfish carcass waste (SDHYCW) - water
- 23 Commercial spray dried hydrolysed fish (SDHYF) - water
- 24 Spray dried hydrolysed salmon hatchery carcasses (SDHYS) - water
- 25 SDHYS - krill
- 26 SDHYS - beef liver
- 27 SDHYS - tuna viscera
- 28 SDHYS - squid
- 29 SDHYS - shrimp

Composition of Major Protein Sources:

	Percent wet weight			
	Moisture	Ash	Fat	Protein
SDHYCW	4.31	3.53	38.93	54.48
SDHYHK	7.53	5.49	16.39	72.83
SDHYF	8.82	6.34	15.24	69.98
SDHYS	3.56	4.41	18.69	75.65
VSM	8.06	8.78	14.61	71.12
VHKM	3.38	15.42	10.34	71.91
STSM	7.32	8.99	14.29	71.15

Ration Formulation/Composition:

Code: 17 (reference control)
Biodiet Starter Ration

Proximate Composition:	#2	#3	1/32"
Moisture (%)	19.98	19.51	20.11
Ash (% wet wt.)	9.90	9.31	9.77
Ash (% dry wt.)	12.37	11.57	12.23
Fat (% wet wt.)	18.58	17.64	18.45
Fat (% dry wt.)	23.22	21.91	23.09
Protein (% wet wt.)	46.91	46.67	48.56
Protein (% dry wt.)	58.62	57.98	60.78

Ration Formulation/Composition:

Code:	18	19	20	21	22	23
Protein source:	VSM	STSM	VHKM	SDHYHK[5]	SDHYCW[5]	SDHYF
"Moist component":	Water	Water	Water	Water	Water	Water
Protein source	42.0	41.98	41.54	60.5	78.0	64.0
Dried whey product[1]	2.0	2.00	2.00			
Wheat germ meal[2]	11.7	11.62	10.36			
Spray dried whole blood	2.0	2.00	2.00	5.4	5.4	5.4
Trace mineral premix[3]	0.1	0.10	0.10	0.1	0.1	0.1
Sodium bentonite	2.0	2.00	2.00	2.0	2.0	2.0
OR vitamin premix[4]	1.5	1.50	1.50	2.0	2.0	2.0
SDHYHK[5]	3.0	3.00	3.00			
SDHYCW[5]	10.0	10.00	10.00			
Herring oil/antioxidant[6]	7.2	7.30	9.00	11.5		12.0
Choline chloride[7]	0.5	0.50	0.50	0.5	0.5	0.5
"Moist component"[8]	(18.0)	(18.00)	(18.00)	(18.0)	(12.0)	14.0
Total	100	100	100	100	100	100
Proximate composition						
Moisture (%)	25.08	24.03	21.93	22.64	15.99	17.80
Ash (% wet wt.)	6.80	6.98	9.66	5.48	4.87	6.35
Ash (% dry wt.)	9.08	9.19	12.37	7.08	5.80	7.72
Fat (% wet wt.)	18.90	19.30	18.94	21.84	30.29	22.79
Fat (% dry wt.)	25.23	25.40	24.26	28.23	36.05	22.72
Protein (% wet wt.)	42.37	43.05	42.76	50.51	48.27	51.94
Protein (% dry wt.)	56.55	56.67	54.77	65.29	57.46	63.19

Code:	24	25	26	27	28	29
Protein source:	SDHYS[5]	SDHYS[5]	SDHYS[5]	SDHYS[5]	SDHYS[5]	SDHYS[5]
"Moist component":	Water	Krill[8]	Beef liver[8]	Tuna viscera[8]	Squid[8]	Shrimp[8]
Protein source	61.0	61.0	61.0	61.0	61.0	61.0
Spray dried whole blood	5.4	5.4	5.4	5.4	5.4	5.4
Trace mineral premix[3]	0.1	0.1	0.1	0.1	0.1	0.1
Sodium bentonite	2.0	2.0	2.0	2.0	2.0	2.0
OR vitamin premix[4]	2.0	2.0	2.0	2.0	2.0	2.0
Herring oil/antioxidant[6]	11.0	11.0	11.0	11.0	11.0	11.0
Choline chloride[7]	0.5	0.5	0.5	0.5	0.5	0.5
"Moist component"[8]	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)	(18.0)
Total	100	100	100	100	100	100
Proximate composition:						
Moisture (%)	19.83	20.10	19.54	17.99	20.98	20.58
Ash (% wet wt.)	4.88	5.13	4.72	5.00	4.99	5.01
Ash (% dry wt.)	6.09	6.42	5.87	6.10	6.31	6.31
Fat (% dry wt.)	23.32	22.68	22.33	23.32	22.94	22.71
Fat (% dry wt.)	29.09	28.38	27.75	28.43	29.03	28.59
Protein (% wet wt.)	52.05	51.98	51.74	53.35	51.86	52.02
Protein (% dry wt.)	64.92	65.06	64.30	65.05	65.63	65.50

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[1]Min. 12% protein, max. 6% moisture, max. 10% ash, max. 3% salt
[2]Min. 23% protein and 7% fat

[3]Gm/lb: Zn, 34.00 ($ZnSO_4$, 84.g/lb); Mn, 34.00 ($MnSO_4$, 94 g/lb); Fe, 4.50 ($FeSO_4 . 7H_2O$, 22.5 g/lb); Cu, 0.70 ($CuSO_4$, 1.75 g/lb); I, 0.23 (KIO_3, 0.38 g/lb); diluted to 1.00 lb with cereal product.

[4]Mg/lb: d-biotin, 18.0; vitamin B_6 535.0 (pyridoxine.HCl, 650 mg); B_{12}, 1.8; vitamin C, 27,000.0 (ascorbic acid); vitamin E, 15,200.0 (water dispersible alpha tocopheryl acetate): folacin, 385.0 (folic acid); Myo-inisitol, 4000.0 (not phytate); vitamin K, 180.0 (menadione sodium bisulfite complex, 545 mg); niacin, 5700.0; d-pantothenic acid, 3200.0 (d-calcium pantothenate, 3478 mg or d,l-calcium pantothenate, 6957 mg; riboflavin, 1600.0; thiamine, 715.0 (thiamine mononitrate, 778 mg); dilute to 1.0 lb with cereal product.

[5]Spray dried bone-free hydrolysate pasteurized at 180°F for ≥ 5.0 min.

[6]Stabilized with 0.4% BHA:BHT (1:1); free fatty acids not more than 3%.

[7]Liquid, 70%

[8]"Moist components" heat pasteurized at 180°F for ≥5.0 min.; liquefaction (hydrolysis) variable depending upon <u>in situ</u> proteolytic activity

[9]( )=Modification in "moist component" required to achieve extrusion of small pellet sizes: code 18-21, 3.0 additional parts of water; code 22, 4.0 additional parts of water; codes 25, 28 and 29, 3.0 additional parts of krill, squid and shrimp, respectively; code 26, 8.0 additional parts of beef liver; code 27, 5.0 additional parts of tuna viscera.

APPENDIX II
Feed Consumption and
Growth Data (0-35 days)

Code/ Rep.	Time (day)/lot weight(g)				Time (day)/average fish weight (g)			
	0	11(A)[1]	11(B)[2]	35	0	11(A)[1]	11(B)[2]	35
17A	260.0	336	275.0	746	0.317	0.435	0.425	1.171
17B	"	335	"	730	0.320	0.441	0.414	1.124
18A	|	333	|	777	0.304	0.432	0.445	1.284
18B	|	395	|	792	0.303	0.453	0.436	1.289
19A	|	362	|	787	0.316	0.460	0.444	1.316
19B	|	328	|	795	0.312	0.432	0.434	1.280
20A	|	327	|	692	0.308	0.426	0.422	1.095
20B	|	329	|	711	0.314	0.429	0.415	1.105
21A	|	368	|	736	0.313	0.455	0.454	1.253
21B	|	349	|	769	0.310	0.445	0.427	1.221
22A	|	316	|	755	0.307	0.446	0.431	1.202
22B	|	351	|	732	0.307	0.425	0.417	1.145
23A	|	298	|	545	0.318	0.381	0.376	0.768
23B	|	288	|	531	0.321	0.402	0.373	0.736
24A	|	302	|	569	0.309	0.383	0.376	0.810
24B	|	318	|	573	0.314	0.385	0.385	0.819
25A	|	330	|	703	0.305	0.430	0.438	1.152
25B	|	336	|	739	0.318	0.430	0.433	1.209
26A	|	344	|	794	0.315	0.453	0.444	1.310
26B	|	357	|	811	0.302	0.477	0.434	1.303
27A	|	335	|	749	0.312	0.449	0.427	1.191
27B	|	339	|	745	0.323	0.451	0.441	1.221
28A	|	328	|	756	0.310	0.458	0.441	1.229
28B	|	323	|	741	0.316	0.450	0.426	1.179
29A	|	343	|	712	0.323	0.443	0.443	1.182
29B	↓	347	↓	750	0.311	0.455	0.431	1.200

APPENDIX II
(Continued)

Code/ Rep	Day/fork length (mm) 0	11(B)[2]	35	Mortality No.	Wt.(g)	Time period (days) /feed (g wet wt) 0-11	11-35
17A	34.76	34.35	50.34	9	3.7	159.6	411.5
17B	34.64	34.21	49.90	14	5.7	159.6	385.8
18A	34.22	33.73	50.22	12	5.2	164.2	444.8
18B	35.45	34.93	50.78	17	6.9	164.2	402.3
19A	34.23	34.31	51.74	20	7.5	163.2	435.4
19B	34.67	33.50	51.66	12	5.1	163.2	449.4
20A	34.17	33.91	48.07	19	7.1	160.6	475.9
20B	34.57	34.00	48.34	19	7.9	160.6	423.7
21A	34.53	33.86	51.69	16	7.3	158.0	373.7
21B	34.64	34.00	49.22	13	6.4	158.0	369.1
22A	34.41	34.10	50.42	9	4.2	161.6	382.7
22B	34.62	34.28	49.62	19	8.4	161.6	411.0
23A	34.81	33.55	42.87	22	7.6	152.8	338.1
23B	35.18	33.84	42.47	17	5.8	152.8	368.0
24A	34.51	33.12	45.07	29	9.6	154.4	340.4
24B	35.12	33.50	45.25	15	6.3	154.4	348.8
25A	33.96	34.40	50.11	17	7.3	158.0	350.9
25B	34.82	34.03	50.85	23	9.1	158.0	363.3
26A	35.54	34.06	51.13	13	6.0	157.0	375.2
26B	34.34	35.80	51.41	12	5.7	157.0	367.4
27A	34.15	33.69	49.84	14	6.7	155.4	358.2
27B	34.48	34.30	49.70	13	6.1	155.4	368.3
28A	34.50	34.85	50.32	8	3.3	159.0	373.9
28B	34.68	33.55	49.59	18	7.4	159.0	363.2
29A	34.79	33.32	50.82	18	7.8	159.0	372.6
29B	34.34	34.00	50.19	13	5.6	159.0	361.8

[1]Fish lot weight or average fish weight prior to lot size reduction.
[2]Fish lot weight, average fish weight or fork length after lot size reduction.

APPENDIX III

Body Composition

Ration code/ Tank Rep.	Percent wet weight			
	Moisture	Ash	Fat	Protein
17A	78.30	2.04	6.10	13.94
17B	78.95	2.06	5.46	14.15
18A	78.56	2.04	5.93	14.33
18B	78.57	2.03	6.02	14.02
19A	77.98	1.96	6.59	13.79
19B	78.25	2.02	6.26	14.26
20A	78.62	2.04	5.84	14.17
20B	78.43	2.01	5.82	14.09
21A	77.21	1.69	7.50	14.47
21B	77.70	1.64	7.29	14.03
22A	77.97	1.68	6.77	14.08
22B	78.10	1.74	6.66	14.25
23A	79.79	1.60	5.79	13.71
23B	79.85	1.60	5.55	13.78
24A	79.73	1.55	5.78	13.64
24B	79.46	1.56	5.91	13.95
25A	78.05	1.65	7.13	14.03
25B	77.95	1.61	7.34	14.29
26A	77.71	1.69	7.21	14.34
26B	77.57	1.68	7.32	14.36
27A	77.89	1.70	7.04	14.27
27B	77.65	1.71	7.18	14.29
28A	77.85	1.66	7.25	14.27
28B	78.22	1.64	7.02	14.21
29A	77.67	1.69	7.10	14.43
29B	77.97	1.65	7.21	14.09

ADDENDUM B
DEVELOPMENT OF RATIONS FOR THE ENHANCED
SURVIVAL OF SALMON

Bonneville Power Administration Project 83-363

Comparative Evaluation of Vacuum Dried Fish Meal
and Spray Dried Hydrolysates to High Quality Commercial
Fish Meals as Protein Sources for Fall Chinook Salmon

Introduction

Vacuum dried and spray dried fish should provide an optimum in protein quality. The low product temperatures achieved during drying using these two procedures markedly limit the degree to which unfavorable changes take place that reduce protein quality.

This investigation was designed to provide a definition of their relative protein quality to high quality commercial meals using small well controlled laboratory scale feeding trials. The design of this investigation also allowed an evaluation of the effect of hydrolysis on protein quality and a test of "moist" and "soft dry" ration formulations. The "soft dry" ration concept could allow the handling of high quality and energy rich rations at ambient atmospheric temperatures eliminating the need for freezing rations.

Experimental

Ration Formulation

Six moist and six soft dry rations containing either high protein herring meal (HPHM), vacuum dried hatchery salmon carcasses (VSM), vacuum dried whole hake (VHKM), spray dried hydrolysed hatchery salmon carcasses (SDHYS) or spray dried hydrolysed whole Pacific hake (SDHYHK) as the major source of protein were formulated and prepared at the Oregon State University Seafoods Laboratory. All rations contained levels of major protein sources which would provide equal protein (6.25 x total Kjeldahl N) to that provided by 40.0 percent VSM. Formulation goals dictated the addition of variable quantities of herring oil to the rations as required to provide a 1:1 total fat:protein caloric ratio (9.0 kcal/g=fat; 4.0 kcal/g=protein). Ration components were milled, mechanically mixed and extruded into 1.2, 1.6, 2.4 and 3.6 mm length diameter pellets. Pelletized ration was placed in airtight plastic freezer containers and frozen and stored at -12°C. Ration protein source allocation to treatment replicate, proximate composition of major protein sources and the formulation and proximate composition of prepared rations are listed in APPENDIX I.

Experimental Fish

Each experimental lot of fish (2 replicate lots/ration treatment) consisted of 225 randomly selected fall chinook (tule stock) (mean weight= 1.26+.044 g; mean fork length= 52.19+1.046 mm). Fish were distributed to 24 tank replicates on 16 February 84.

Husbandry

Fish were held in cylindrical (0.92 m diameter x 0.72 m depth), center drained, fiberglass tanks located in-doors at the Oregon Department of Fish and Wildlife Clackamas Laboratory. Lighting by overhead fluorescent lights was controlled with timers which were adjusted to provide a diurnal 9 hour light (14.5 hours dark cycle, separated by 0.25 hours morning and evening periods of simulated twilight). Tank volumes were adjusted to 3300 liters and each was supplied with uncirculated well water (12 C) at a rate of 10.0 liters/minute. Outfall dissolved oxygen concentrations, measured by Winkler titrations at biweekly intervals, did not fall below 8.0 ppm.

Fish were fed by hand one to four times daily, depending on observed feeding response, so that all feed present was consumed. Rations were withheld on weighing days. Daily feeding levels were based on a metric dry weight hatchery constant of 177.8. Feeding rates were adjusted at biweekly intervals. Fish from each tank were weighed collectively every 14 days, and individually measured to the nearest mm fork length at the end of each 28 day interval. Fish were supplied the smallest (1.2 mm) pellets until they reached an average weight of about 2.7 g (17 days); 1.6 mm pellets until they were about 4.6 g (14 days); 2.4 mm pellets until they were about 13 g (46 days) and 3.2 mm pellets until the end of the trial (38 days). Feeding was terminated on 11 June 84 after 115 days of feeding.

At the conclusion of each 28-day interval, growth in length and weight were assessed, and specific growth rates, protein efficiency and feed/gain ratios were computed. Upon termination, 10 fish from each tank were pooled for the determination of whole body composition. An additional 10 fish from each tank were collected for hematocrit determination and gross examination for internal and external signs of nutritional disorders.

Results of growth responses were analysed using a factorial analysis of variance design. Factorial level means and treatment means were separated using Fisher's LSD test at a factor significance level of P=.05.

Results and Discussion

Moist rations produced growth rates superior ($P \geq .001$) to soft dry rations yielding heavier ($P \geq .001$) and longer ($P \geq .001$) fish (Table 1). Moist and soft dry rations containing steam tube dried salmon meal (STSM) and spray dried hydrolysed salmon (SDHYS) produced equal (P=.05) growth rates and fish weights. Moist and soft dry rations containing high protein herring meal (HPHM), STSM and SDHYS possessed equal lengths (P=.05). Moist rations containing HPHM, vacuum dried salmon meal (VSM), vacuum dried hake meal (VHKM), and spray dried hydrolysed hake (SDHYHK) all produced growth superior (P=.05) to their counterpart in the soft dry ration. Soft dry rations containing HPHM, VSM, VHKM and SDHYHK yielded final fish weights that were less (P=.05) than moist rations. Fish supplied soft dry rations containing VSM, VHKM and SHYHK were shorter ($P=.05$) than similar moist rations. The condition factor computed for fish receiving the moist and soft dry rations did not vary significatly ($P\leq.05$).

Protein sources significatly effected specific growth rate ($P\geq..001$), final mean weight ($P\geq.005$) and final fork length ($P\geq.001$). SDHYS produced the best growth response as measured by all three parameters, but was equal ($P=.05$) to VSM. STSM produced a specific growth rate equal ($P=.05$) to both SDHYS and VSM. VHKM produced a growth response as measured by specific growth rate, final mean weight and fork length that was inferior ($P=.05$) to all other protein sources. HPHM and SDHYHK produced growth responses intermediate between SDHYS-VSM and VDHKM. Protein source did not significantly ($P=.05$) alter the condition factor of fish.

Hydrolysis of both salmon and hake protein sources favorably enhanced specific growth rate in both moist and soft dry rations. Improvement, however, was not significant ($P\leq.05$). VSM produced slightly (NS $P=.05$) heavier and longer fish than its hydrolysed counterpart in moist rations, but significantly ($P=.05$) lighter and shorter fish in soft dry rations. SDHYHK produced heavier and longer fish than its intact counterpart in both moist and soft dry ration formulations. This relationship was significant ($P=.05$) in all cases except with regard to the final weight of fish supplied the soft dry ration containing these protein sources.

VSM performed better than commercially prepared STSM in moist rations. VSM produced heavier and longer fish ($P=.05$) with a slightly (NS $P=.05$) better specific growth rate. Conversely, STSM produced a slightly (NS $P=.05$) better specific growth rate in soft dry rations which yielded somewhat (NS $P=.05$) larger, but slightly (NS $P=.05$) shorter fish.

Inspection of individual treatment means revealed only a few instances of a relative effect of protein source on the performance of two ration types. Ration x protein source interaction effects were not significant ($P\leq.05$) with regard to specific growth rate, final fish weight or fork length.

Table 1. Growth response of fish

Ration type	Protein source	Initial mean wt.(g)	Final mean wt.(g)	Specific growth rate[4]	Fork length(mm)	Condition factor[5]
Moist	HPHM	1.242	24.65^{bcd}	2.596^{abcd}	125.8^{ab}	1.159
	VSM	1.273	26.60^{a}	2.642^{a}	128.0^{a}	1.268
	VHKM	1.259	23.90^{cde}	2.558^{bcde}	124.1^{bc}	1.249
	STSM	1.248	24.95^{bcd}	2.603^{abc}	125.5^{ab}	1.260
	SDHYS	1.235	26.00^{ab}	2.648^{a}	127.6^{a}	1.249
	SDHYHK	1.277	26.00^{ab}	2.620^{ab}	127.7^{a}	1.248
Soft dry	HPHM	1.255	22.95^{ef}	2.526^{ef}	123.4^{bc}	1.220
	VSM	1.268	23.45^{def}	2.534^{def}	124.3^{bc}	1.219
	VHKM	1.266	20.60^{g}	2.425^{g}	119.3^{d}	1.213
	STSM	1.255	23.55^{cdef}	2.550^{cdef}	124.0^{bc}	1.235
	SDHYS	1.268	25.15^{abc}	2.596^{abcd}	127.0^{a}	1.227
	SDHYHK	1.264	22.10^{fg}	2.487^{fg}	122.1^{c}	1.210

Analysis of Variance: 2x6 factorial design (n=2)

	F-values			
Ration (R)	60.41[2]	55.69[2]	41.41[2]	1.69[1]
Protein source (PS)	9.28[2]	8.44[3]	10.21[2]	1.54[1]
PxPS	1.50[1]	1.46[1]	2.68[1]	1.40[1]

Ranking of Protein Source Level Means:

Final mean wt.(g) SDHYS> VSM> STSM> SDHYHK> HPHM> VHM

Specific growth rate SDHYS> VSM> STSM> HPHM> SDHKHY> VHKM

Fork length (mm) SDHYS> VSM>SDHYHK> STSM> HPHM> VHKM

Ranking of Ration Level Means:

Mean wt (g)	Moist	>	Soft dry
Specific growth rate	Moist	>	Soft dry
Fork length (mm)	Moist	>	Soft dry

[1]NS $P \leq .05$ [2] Sig $P \geq .001$ [3] Sig $P \geq .005$
[4]ln final average wt.-ln initial average wt./No. days x 100
[5]100,000 x wt.(g)/(length-mm)^3
Value means in a column with same exponent letter did not vary significantly (P=.05)
Level means with same underline did not vary significantly (P=.05)

Moist rations produced a superior growth rate over soft dry rations through the consumption of more ($P \geq .005$) feed and superior feed (dry wt.) ($P \geq .001$) and protein ($P \geq .001$) conversion (Table 2). Inspection of individual treatment means revealed moist rations to be superior ($P=.05$) to soft dry rations in all cases except with regard to the consumption (dry wt.) of feed containing SDHYS and with regard to the conversion (dry wt.) of rations containing HPHM and STSM (NS $P=.05$). All moist ration protein treatments were shown to have better ($P=.05$) protein efficiencies than their soft dry counterparts.

Protein source did not significantly ($P \leq .05$) effect feed consumption (dry wt.). Rations containing protein sources derived from salmon were consumed in the greatest quantities in the following order VSM>STSM>SDHYS. The preference for rations containing salmon protein sources appeared to be the reason for a significant ($P \geq .025$) ration x protein source interaction observed for feed (dry wt.) consumption. Salmon protein sources were consumed better in soft dry rations in relation to moist rations than other protein sources.

Feed conversion (dry wt.) was significantly ($P \geq .001$) altered by protein source. SDHYS yielded a conversion rate superior ($P=.05$) to all other protein sources. VSM, SDHYHK, HPHM and STSM produced equal ($P=.05$) conversion rates in the order listed. VHKM produced the poorest ($P=.05$) conversion rate. Ration and protein source did not interact in a significant ($P \leq .05$) manner.

Protein efficiencies varied ($P \geq .001$) by protein source. SDHYS, HPHM and VSM yielded equal ($P=.05$) and the best efficiencies in order. VSM produced efficiencies equal ($P=.05$) to STSM. VHKM and SDHYHK possessed equal ($P=.05$) efficiencies; SDHYHK was equal ($P=.05$) to STSM. Ration and protein source did not ($P \leq .05$) interact to effect protein efficiencies.

Hydrolysis of protein sources altered feed (dry wt.) consumption, feed (dry wt.)/ gain, and protein efficiencies in varying degrees. SDHYHK was consumed in larger quantities in moist rations and on an equal basis in the soft dry formulation ($P=.05$). Conversely SDHYS was consumed in larger amounts in the soft dry ration and in smaller quantities in the moist ration than intact VDSM protein. SDHYS and SDHYHK yielded better feed (dry wt.) conversions and protein efficiencies than their intact meal protein counterparts. This observation was significant ($P=.05$) in all cases for feed (dry wt.)/gain except for the moist ration containing SDHYS. Protein efficiency differences did not vary significantly ($P=.05$).

VSM appeared to perform slightly better than its commercial steam tube dried counterpart. More ($P=.05$) VSM was consumed in moist rations and an equal ($P=.05$) amount in soft dry rations than STSM. VSM was converted slightly better ($P=.05$) in moist rations and in an equal ($P=.05$) manner in soft dry rations. VSM produced better (NS $P=.05$) protein efficiency ratios than STSM in both moist and soft dry rations.

Table 2. Feed consumption and conversion

Ration type	Protein source	Feed (dry wt.)(g)	Feed (wet wt.)/gain	Feed (dry wt.)/gain	Protein efficiency
Moist	HPHM	3488.9^{cde}	$.879^{ab}$	$.667^{cd}$	2.709^{ab}
	VSM	3680.0^{a}	$.855^{bcd}$	$.647^{de}$	2.713^{ab}
	VHKM	3472.1^{de}	$.901^{a}$	$.687^{bc}$	2.596^{bcd}
	STSM	3570.2^{bc}	$.905^{a}$	$.673^{bcd}$	2.648^{abc}
	SDHYS	3474.2^{de}	$.837^{cde}$	$.626^{e}$	2.764^{a}
	SDHYHK	3610.0^{ab}	$.873^{abc}$	$.651^{de}$	2.636^{abc}
Soft Dry	HPHM	3360.1^{f}	$.819^{de}$	$.691^{bc}$	2.554^{cde}
	VSM	3419.5^{ef}	$.814^{e}$	$.687^{bc}$	2.490^{def}
	VHKM	3263.7^{g}	$.889^{a}$	$.751^{a}$	2.303^{g}
	STSM	3446.0^{def}	$.834^{de}$	$.686^{bc}$	2.448^{ef}
	SDHYS	3508.7^{cd}	$.777^{f}$	$.657^{d}$	2.569^{cde}
	SDHYHK	3259.0^{g}	$.843^{bcde}$	$.698^{b}$	2.385^{fg}

Analysis of Variance : 2x6 factorial design (n=2)

	F-value			
Ration (R)	18.14[3]	45.00[2]	48.56[2]	119.16[2]
Protein source (PS)	1.75[1]	13.02[2]	15.32[2]	11.48[2]
RxPS	4.18[4]	1.74[1]	1.88[1]	1.10[1]

Ranking of Protein Sources Level Mean:

Feed (dry wt)(g)	VSM> STSM> SDHYSM> SDHYHK> HPHM> VHKM
Feed (wet wt)/gain	VHKM> STSM> SDHYHK> HPHM> VSM> SDSM
Feed (dry wt) gain	VHKM> STSM> HPHM> SDHYHK> VSM> SDHYS
Wt. gain/feed protein	SDHYS> HPHM> VSM> STSM> SDHYHK> VHKM

Ranking of Protein Sources Level Mean:

Feed (dry wt)(g)	Moist > Soft dry
Feed (wet wt)/gain	Moist > Soft dry
Feed (dry wt.)/gain	Soft dry> Moist
Protein efficiency	Moist > Soft dry

[1]NS $P\leq.05$ [2]Sig $P\geq.001$ [3]Sig. $P\geq.005$ [4]Sig. $P\geq.025$

Value means in columns with same exponent letters did not vary significantly (P=.05)

Level means with same underline did not vary significantly P=.05

Body moisture, fat (dry wt.) and protein (dry wt.) contents and blood hematocrit levels were not significantly ($P \leq .05$) effected by either ration type of protein source (Table 3). Body ash (dry wt.) was not ($P \leq .05$) effected by ration type, but was significantly ($P \geq .025$) altered by ration protein source. Inspection of individual treatment means indicted that rations (both moist and soft dry) containing SDHYS and SDHYHK possessed the lowest body ash contents. These protein sources also produced complete rations with the lowest ash contents.

Table 3. Body composition and blood hematocrit

Ration type	Protein source	Body Moisture (%)	Body composition (% dry wt) Ash	Fat	Protein	Hematocrit %
Moist	HPHM	72.14	7.81^{ab}	36.85	58.43	46.0
	VSM	72.01	7.54^{bcde}	36.94	58.07	40.7
	VHKM	72.69	7.73^{abc}	39.02	58.27	42.4
	STSM	72.61	7.85^{ab}	36.00	58.55	41.8
	SDHYS	71.95	7.13^{e}	37.84	57.83	42.0
	SDHYHK	72.15	7.21^{de}	38.36	57.99	42.8
Soft Dry	HPHM	72.43	7.58^{abcde}	36.33	58.00	41.7
	VSM	72.91	8.02^{a}	36.83	58.63	39.7
	VHKM	72.86	7.69^{abc}	37.11	58.64	41.7
	STSM	71.60	8.04^{a}	36.42	58.68	42.9
	SDHYS	72.85	7.34^{cde}	39.69	56.38	43.5
	SDHYHK	72.47	7.67^{abcd}	37.76	58.63	41.9

Analysis of Variance: 2x6 factorial design (n=2):

	F-value				
Ration (R)	2.00[1]	4.22[1]	0.05[1]	0.01[1]	1.45[1]
Protein source (PS)	1.96[1]	4.90[2]	1.61[1]	1.05[1]	2.36[1]
RxPS	0.60[1]	1.66[1]	0.61[1]	0.57[1]	1.75[1]

Ranking of Protein Source Level Means:

Body Ash (% dry wt.) STSM > VSM > VHKM > HPHM > SDHYHK > SDHYS

Ranking of Ration Level Means:

Body ash (% dry wt.) Soft dry > Moist

[1]NS $P \leq .05$ [2]Sig $P \geq .025$

Value means in a column with same exponent letter did not vary significantly (P=.05)

Level means with same underline did not vary significantly (P=.05)

The results of this investigation clearly identifies dried products of salmon to be superior sources of protein for the growth of salmon fingerlings. Dried salmon proteins produced rations that were consumed and converted in a superior manner. Conversely, hake proteins as vacuum dried meal prepared under the best of conditions proved to be distinctly inferior to salmon as a source of proteins for fingerlings and even inferior to high protein commercial herring meal.

Hydrolysis appeared to significantly improve the quality of hake and salmon proteins. This is quite remarkable since the intact protein of the vacuum dried meals to which the hydrolysates were being compared should have been essentially lacking in heat damage from the drying process. Although it seems plausible that hydrolysis could increase digestibility and in turn favorably influence conversion, one other major difference in the composition of these two product existed. In addition to hydrolyzing, bone was removed from the liquified fish prior to spray drying. This process markedly reduced the ash content of the dry product significantly reducing the ash content of the subsequent ration formulation. Since bone is removed, this process would clearly reduce macro-mineral content (Ca, Mg, etc.) and completely alter the mineral balance in complete ration formulations.

VSM was shown to be only slightly better than commercial prepared steam tube dried meal with the latter being equivalent to HPHM. It is clear that the very high quality commercial meals included in this feeding trial can function nearly on an equal basis for growth. Their relative effect on survival, however, is in question.

This test of the soft dry ration concept with rapidly growing fingerlings showed it to be generally inferior to the more moist rations. Fish supplied the soft dry ration consumed less feed and converted it less efficiently into body weight. It should also be noted that the availability of a unique component vital in producing extrusion characteristics is no longer available on the market making the formulation of this type of ration and its intended means of production impractical.

APPENDIX I
Ration Description

Ration Protein Source Description/Composition

Protein Source Description

Ration code	Description
#31 & 37-HPHM	High protein commercial herring meal
#32 & 38-VSM	Vacuum dried salmon meal
#33 & 39-VHKM	Vacuum dried hake meal
#34 & 40-STSM	Steam tube dried commercial salmon meal
#35 & 41-SHYS	Spray dried hydrolyzed salmon (bone-free)
#36 & 42-SHYHK	Spray dried hydrolyzed hake (bone-free)

Protein Source Proximate Composition

	Percent			
Ration code	Moisture	Ash	Fat	Protein
#31 & 37-HPHM	5.97	13.92	12.74	70.16
#32 & 38-VSM	8.06	8.78	14.61	71.12
#33 & 39-VHKM	3.38	15.42	10.34	71.91
#34 & 40-STSM	7.32	8.99	14.29	71.15
#35 & 41-SHYS	3.10	4.42	18.47	75.73
#36 & 42-SHYHK	7.09	5.51	16.81	72.83

Ration Formulation/Composition

Moist Ration Formulation/Composition

	Ration No. code - Fish Meal Protein Source/Percent					
	#31-HPHM	#32-VSM	#33-VHKM	#34-STSM	#35-SHYS	#36-SHYHK
Protein source	40.55	40.00	39.56	39.98	37.56	39.06
Dried whey product[1]	2.00	2.00	2.00	2.00	2.00	2.00
Wheat germ meal[2]	12.45	13.66	10.90	13.55	15.66	15.29
Spray dried blood meal[3]	2.00	2.00	2.00	2.00	2.00	2.00
OR trace mineral premix[4]	0.10	0.10	0.10	0.10	0.10	0.10
Sodium bentonite	2.00	2.00	2.00	2.00	2.00	2.00
OR vitamin premix[5]	1.50	1.50	1.50	1.50	1.50	1.50
Spray dried whole fish hydrolysate[6]	3.00	3.00	3.00	3.00	3.00	3.00
Spray dried carcass waste hydrolysate[7]	10.00	10.00	10.00	10.00	10.00	10.00
Herring oil/antioxidant[9]	7.90	7.24	8.94	7.37	6.18	6.55
Choline chloride[10]	0.50	0.50	0.50	0.50	0.50	0.50
Water	18.00	18.00	19.50	18.00	19.50	18.00
Total	100	100	100	100	100	100

Proximate composition

	#31-HPHM	#32-VSM	#33-VHKM	#34-STSM	#35-SHYS	#36-SHYHK
Moisture (%)	24.09	24.27	23.74	25.64	24.38	25.47
Ash (% wet wt)	8.84	6.85	9.50	6.90	5.03	5.49
Ash (% dry wt)	11.64	9.04	12.46	9.28	6.65	7.37
Fat (% wet wt)	18.46	18.95	18.84	18.86	18.50	18.08
Fat (% dry wt)	24.32	25.02	24.70	25.36	24.46	24.26
Protein (% wet wt)	41.99	43.11	42.43	41.79	43.21	43.43
Protein (% dry wt)	55.31	56.92	55.64	56.20	57.14	58.27

Soft Dry Ration Formulation/Description

	#37-HPHM	#38-VSM	#39 VHKM	#40-STSM	#41-SHYS	#42 SHYHK
Protein source	40.55	40.00	39.56	39.98	37.56	39.06
Dried whey product[1]	6.00	6.00	6.00	6.00	6.00	6.00
Wheat germ meal[2]	1.85	3.85	1.58	3.74	7.32	5.48
Spray dried blood[3]	6.00	6.00	6.00	6.00	6.00	6.00
OR trace mineral premix[4]	0.10	0.10	0.10	0.10	0.10	0.10
Sodium bentonite	2.00	2.00	2.00	2.00	2.00	2.00
OR vitamin premix[5]	1.50	1.50	1.50	1.50	1.50	1.50
Spray dried fish hydrolysate[6]	3.00	3.00	3.00	3.00	3.00	3.00
Spray dried carcass waste hydrolysate[7]	10.00	10.00	10.00	10.00	10.00	10.00
Spray dried cell cream[8]	8.00	8.00	8.00	8.00	8.00	8.00
Herring oil/antioxidant[9]	11.50	10.05	11.76	10.18	9.02	9.36
Choline chloride[10]	0.50	0.50	0.50	0.50	0.50	0.50
Water	9.00	9.00	10.00	9.00	9.00	9.00
Total	100	100	100	100	100	100
Proximate composition						
Moisture (%)	14.66	15.65	15.36	17.46	15.44	17.21
Ash (% wet wt)	10.79	8.44	11.00	8.61	6.82	7.14
Ash (% dry wt)	12.29	10.00	13.00	10.43	8.06	8.62
Fat (% wet wt)	21.33	21.12	20.86	21.07	21.18	21.20
Fat (% dry wt)	24.99	25.04	24.64	25.53	25.05	25.61
Protein (% wet wt)	47.80	49.31	48.49	49.26	50.10	49.70
Protein (% dry wt)	56.01	58.46	57.29	59.68	59.25	60.03

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[1]Min. 12% protein, max. 6% moisture, max. 10% ash, max. 3% salt

[2]Min. 23% protein and 7% fat

[3]Spray dried whole blood

[4]Gm/lb: Zn, 34.00 ($ZnSO_4$, 84 g/lb); Mn, 34.00 ($MnSO_4$, 94 g/lb); Fe, 4.50 ($FeSO_4 \cdot 7H_2O$, 22.5 g/lb); Cu, 0.70 ($CuSO_4$, 1.75 g/lb); I, 0.23 (KIO_3, 0.33 g/lb; dilute to 1.00 lb with cereal product.

[5]Mg/lb: d-biotin, 18.0; vitamin B_6 535.0 (pyridoxine.HCl, 650 mg); B_{12}, 1.8; vitamin C, 27,000.0 (ascorbic acid); vitamin E, 15,200.0 (water dispersible alpha tocopheral acetate); folacin, 385.0 (folic acid); myo-inositol, 4000.0 (not phytate); vitamin K, 180.0 (menadione sodium bisulfite complex, 545 mg); niacin, 5700.0; d-pantothenic acid, 3200.0 (d-calcium pantothenate, 3478 mg or d,l-calcium pantothenate, 6957 mg; riboflavin, 1600.0; thiamine, 715.0 (thiamine mononitrate, 778 mg); dilute to 1.0 lb with cereal product.

[6]Spray dried bone-free hydrolysate of whole hake pasteurized at 180°F for ≥5.0 min.

[7]Spray dried bone-free hydrolysate of groundfish carcass waste pasteurized at 180°F for ≥5.0 min.

[8]Dried glutamic acid fermentation product (<u>Corynebacterium lilium</u> cells recovered from the fermentation of sugar beet molasses to glutamic acid in the production of monosodium glutamate).

[9]Herring oil; stabilized with 0.04% BHA;BHT (1:1); free fatty acids not more than 3%.

[10]Liquid, 70%

[11]Proximate composition of rations #37 and #40 listed represent the composition of 3/64 and 1/16" pellet sizes. The proximate analysis for 3/32 and 1/8" pellet sizes are listed below:

	Percent wet wt				Percent dry wt		
	Moisture	Ash	Fat	Protein	Ash	Fat	Protein
#37	15.77	10.62	21.26	47.78	12.61	25.24	56.72
#40	17.78	8.48	20.90	48.91	10.31	25.42	59.49

APPENDIX II
Growth Response Data

Ration type	Lot No /Rep	Initial /final No. fish	Initial Fork length(mm)	Initial Lot wt.(g)	Final Fork length(mm)	Final Lot wt.(g)	Final Hematocrit (%)	Feed (g wet wt)	Mortality (No. fish)
Moist	31A	225/224	51.76(2.77)	277	125.69(8.42)	5480	46.2(2.4)	4564.3	1[0]
"	31B	225/222	52.63(2.63)	282	126.01(9.06)	5498	45.8(3.1)	4627.8	3[1]
"	32A	225/224	51.77(2.76)	295	128.29(9.97)	6077	39.5(4.3)	4970.6	1[0]
"	32B	225/225	52.34(2.99)	278	127.66(9.77)	5863	42.0(3.5)	4748.1	0[0]
"	33A	225/222	51.90(2.89)	283	123.08(10.07)	5232	41.1(4.7)	4537.5	3[0]
"	33B	225/224	52.73(2.64)	284	125.12(9.52)	5396	43.7(2.7)	4568.5	1[0]
"	34A	225/222	51.39(2.75)	283	124.39(9.18)	5363	40.3(5.5)	4730.9	3[1]
"	34B	225/224	52.76(2.64)	279	126.65(9.60)	57.62	43.4(2.3)	4871.6	1[0]
"	35A	225/224	51.22(2.70)	276	125.60(9.86)	5503	42.0(3.4)	4430.7	1[0]
"	35B	225/224	52.58(2.91)	280	129.62(10.06)	6148	42.1(3.1)	4851.5	1[0]
"	36A	225/224	52.58(2.85)	287	127.78(10.86)	5854	44.0(3.0)	4819.4	1[1]
"	36B	225/223	52.70(2.69)	288	127.63(9.55)	5570	41.6(2.1)	4867.9	2[1]
Soft dry	37A	225/222	52.50(2.86)	280	123.52(8.64)	5135	41.5(3.1)	3934.0	3[0]
"	37B	225/223	51.61(2.46)	285	123.32(8.63)	50.78	41.9(2.8)	4032.1	2[1]
"	38A	225/224	51.93(2.93)	288	124.41(10.06)	52.55	40.4(3.0)	3980.5	1[1]
"	38B	225/225	52.70(2.62)	283	124.11(9.70)	52.55	39.0(2.7)	4127.3	0[0]
"	39A	225/224	52.39(2.78)	292	118.47(9.85)	45.34	42.1(2.6)	3830.3	1[0]
"	39B	225/225	52.45(2.87)	278	120.08(9.13)	4714	41.3(2.3)	3881.8	0[0]
"	40A	225/225	51.49(2.78)	288	123.01(9.85)	5180	43.2(2.0)	4130.1	0[0]
"	40B	225/225	52.58(2.87)	282	125.08(9.09)	5431	42.5(1.9)	4248.5	0[0]
"	41A	225/223	51.38(2.71)	289	126.71(10.98)	5616	41.3(2.1)	4198.7	2[0]
"	41B	225/224	52.60(2.84)	282	127.32(9.22)	5624	45.7(1.8)	4100.0	1[0]
"	42A	225/224	52.74(2.89)	288	122.66(9.95)	4948	43.2(2.4)	3900.5	1[0]
"	42B	225/224	52.20(2.68)	281	122.15(8.83)	4945	40.5(2.3)	3971.5	1[0]

()=Standard deviation
[]=No. fish specifically identified as billed during weighing or as "jump outs"

APPENDIX III
Body Composition

Ration type	Lot No. /Rep.	Percent wet weight			
		Moisture	Ash	Fat	Protein
Moist	31A	71.78	2.17	10.64	16.45
"	31B	72.50	2.18	9.90	16.11
"	32A	71.17	2.08	11.26	16.19
"	32B	72.85	2.14	9.46	16.29
"	33A	73.21	2.09	9.65	15.75
"	33B	72.18	2.13	11.69	16.07
"	34A	72.81	2.17	9.65	16.16
"	34B	72.42	2.13	10.07	15.91
"	35A	71.82	2.04	10.62	16.18
"	35B	72.09	1.96	10.61	16.26
"	36A	71.83	2.04	10.86	16.16
"	36B	72.47	1.98	10.51	16.14
Soft dry	37A	72.78	2.00	9.96	15.92
"	37B	72.08	2.18	10.70	16.06
"	38A	72.86	2.17	10.02	15.78
"	38B	72.96	2.18	9.94	15.99
"	39A	73.21	2.00	9.75	15.92
"	39B	72.52	2.18	10.40	15.90
"	40A	72.94	2.17	9.86	15.99
"	40B	72.87	2.19	9.88	15.81
"	41A	71.27	2.09	11.46	16.14
"	41B	71.94	2.08	11.08	15.88
"	42A	72.85	2.09	10.28	15.96
"	42B	72.47	2.11	10.37	16.10

ADDENDUM C

DEVELOPMENT OF RATIONS FOR THE ENHANCED SURVIVAL OF SALMON

Bonneville Power Administration Project 83-363

Influence of Ration on the Survival of Coho Salmon
I. 1982 Brood Coho Salmon Rearing Investigation
Oregon Department of Fish and Wildlife Sandy Hatchery

Introduction

The survival of hatchery salmonids is dependent upon a number of factors including time of release, natural food abundance, fish size and the health and/or quality of smolts. These factors determine survival from predation, ability to acquire sustainable nutrients under natural conditions, vitality to surmount man made impediments to seaward migration and adaptation to a sea water environment. It is believed that the nutritional characteristics of feed utilized to rear hatchery salmonids play an important role in how smolts overcome impediments to their survival. Of primary nutritional importance, is the quality of the protein complement of the ration.

This investigation was designed to evaluate the rearing of coho salmon with rations containing a high quality protein complement and to release tagged fish for a future measurement of the effect of ration regimes on survival. Released tagged 1982 brood coho salmon represent the first replicate in an evaluation of the influence of ration on survival. The survival of this brood of fish will be evaluated from tags recovered from the fishery and at the hatchery during 1984-85.

Husbandry Protocol

Pond Stocking

Fish (1982-brood coho; Sandy stock) were randomly distributed (in 10 lb lots) into 6 ponds to a stocking density of approximately 59,000 fish/pond. Size at stocking time averaged 2.4 g/fish. Stocking was carried out on 18 May 83 at the Oregon Department of Fish and Wildlife Sandy Hatchery.

Rearing Schedule

Feeding of test rations was initiated on 27 June 83. The determined weight and number of fish/pond at initiation are listed in Appendix IV and the computed average fish weight is listed in Appendix V. Fish were reared under experimental hatchery conditions and released on 30 April 84. The total number of fish released is listed in Appendix IV.

Rations

Duplicate ponds were fed (1) a control Oregon pellet-2 formulation, (2) a test ration containing vacuum dried whole salmon meal as the major protein source and (3) one containing vacuum dried whole hake meal. A summary of the Oregon-2 formulation specifications (Oregon Department of Fish and Wildlife Specifications, July 1982) and the formulation of the two test rations is listed in Appendix I.

The control Oregon pellet-2 formulation was obtained from the normal Sandy Hatchery feed supply. Test rations were formulated and prepared at the Oregon State University Seafoods Laboratory utilizing vacuum dried meals produced by a commercial firm according to requested specifications.

Control ration composition was assessed by sampling the entire feed supply of the hatchery by production date. Test rations were sampled for composition determination by lot during production. Ration composition information on control and test rations is listed in Appendix II.

Feeding

All lots of fish were fed Oregon pellet-2 formulation from stocking (18 May 83) until the initiation of test feeding on 27 June 83. Fish receiving the Oregon pellet-2 ration were fed according to a feeding schedule specific for Sandy Hatchery (approximating 60%, ad lib.) and designed to yield 25 g/fish at release. Fish receiving rations containing vacuum dried salmon and hake meals were fed on a more restricted schedule (about 20% of the control fish) to yield equal sized fish.

The quantity of feed supplied all ponds was recorded and the quantity of feed supplied/pond is listed in Appendix IV. Computation of feed (dry wt.), feed protein and feed fat consumed for control rations was based upon the mean composition of 3/32" and 1/8" pellet sizes composing the entire food supply of the hatchery. These computations for the test ration were based upon the quantity and composition of the actual production lots fed. Computations are listed in Appendix III.

Fish Marking

Fish were injected with destinctive coded wire tags and marked with an adipose fin clip between 20 Oct. - 11 Nov 83 at a rate that would yield a release of approximately 27,000 fish/pond. The actual number of tagged fish released/pond is listed in Appendix IV.

Characterization of Released Fish

Just prior to release, triplicate samples of fish from each pond were obtained for proximate analysis and average blood hematocrit levels and fork lengths were determined. The proximate compositions of fish are listed in Appendix VI. Average blood hematocrits and fork lengths with numbers of fish involved in these estimates of pond populations are listed in Appendix IV.

Rearing Results

Fish in numbers listed on Table 1 were reared on test rations from 27 June 83 to release on 30 April 84. Tagged fish (injected with coded wire tags and marked with an adipose fin clip between 20 Oct - 4 Nov 83) composed approximately 45% of the released population (Table 1). Mortality during the rearing period ranged from 0.88 - 1.49% of the pond replicate populations (Table 1). Average mortality for fish supplied with test rations did not vary significantly ($P \leq .05$) from control fish supplied with the Oregon pellet-2 formulation.

Table 1. Number of fish reared and mortality

Ration	Pond code	Binary code	Initial No. fish	No. fish released: Tagged	No. fish released: Total	Mortality: No. fish	Mortality: Percent[1]
Control	4	7-29/31	58577	25763	57913	664	1.13
	17	7-29/6	58452	26983	58069	386	0.66
	Mean	-	-	-	-	-	0.89
Salmon meal	5	7-29/12	58653	25250	57594	1063	1.81
	14	7-29/9	58610	26573	58100	514	0.88
	Mean	-	-	-	-	-	1.34
Hake meal	7	7-29/10	58436	26654	57772	669	1.14
	16	7-29/7	58562	26095	57691	875	1.49
	Mean	-	-	-	-	-	1.31

[1]Mean values in column did not vary significantly ($P \leq .05$)

Fish were reared from 4.20 - 4.40 g to 26.13 - 26.99 g/fish at release under a feeding schedule designed to yield fish of equal weight approximating 25 g/fish (Table 2). This schedule produced an average weight and length for fish supplied test rations that did not vary significantly ($P \leq .05$) from control fish.

Table 2. Weight of fish reared and fish size

Ration:	Control			Salmon meal			Hake meal		
Pond code:	4	17	Mean	5	14	Mean	7	16	Mean
Initial wt. of fish:									
Total (kg)	245.8	249.9	-	250.8	253.1	-	257.2	248.1	-
Total (lb)	542	551	-	553	558	-	567	547	-
G/fish[1]	4.20	4.28	4.24	4.28	4.32	4.30	4.40	4.24	4.32
Fish/lb	108.1	106.1	-	106.1	105.0	-	103.1	107.1	-
Release wt. of fish:									
Total (kg)	1555.4	1546.2	-	1550.7	1568.2	-	1505.9	1507.8	-
Total (lb)	3429.1	3408.8	-	3418.7	3457.3	-	3364.0	3324.1	-
G/fish[1]	26.86	26.63	26.74	26.92	26.99	26.95	26.41	26.13	26.27
Fish/lb	16.9	17.0	-	16.8	16.8	-	17.2	17.3	-
Length at release(mm)[1]	138.0	137.2	137.6	137.0	137.8	137.4	136.5	136.3	136.4

[1] Mean values in a row did not vary significantly ($P \geq .05$)

The feeding schedule designed to produce an equa_ fish size for all rations yielded feed consumptions for salmon and hake meal rations that were 81 and 85%, respectively, of the consumption of fish supplied Oregon pellet control ration (Table 3). The variation in consumption required to produce equal fish sizes varied significantly both on a wet ($P \geq .001$) and dry ($P \geq .005$) weight basis. Consumption of both test rations was significantly ($P \geq .05$) less than that of the Oregon pellet control ration on either a wet or dry weight basis. Significantly ($P = .05$) more hake meal ration than salmon meal ration was required to produce fish of equal size.

Table 3. Feed consumption and conversion

Ration	Pond code	Feed consumption: Wet wt. (kg)[4]	Feed consumption: Dry wt. (kg)[3]	Feed(wet wt.)/gain[3]	Feed(dry wt.)/gain[3]	Feed protein/ body protein gain[2]
Control	4	1961.3 (4324)[1]	1393.8 (3072.9)	1.50	1.06	3.11
	17	1950.4 (4300)	1386.3 (3055.8)	1.50	1.07	3.18
	Mean	1955.8[a]	1390.0[a]	1.50[a]	1.07[a]	3.14[a]
Salmon meal	5	1593.9 (3514)	1193.6 (2631.4)	1.23	.92	2.96
	14	1583.0 (3490)	1184.8 (2612.2)	1.20	.90	2.93
	Mean	1588.4[b]	1189.2[b]	1.21[b]	.91[b]	2.95[b]
Hake meal	7	1665.1 (3671)	1251.3 (2758.6)	1.31	.99	3.16
	16	1665.1 (3671)	1251.3 (2758.7)	1.32	.99	3.22
	Mean	1665.1[c]	1251.3[c]	1.32[c]	.99[c]	3.19[a]

[1]( ): wt. in lb

Mean values varied significantly: [2]$P \geq .05$; [3]$P \geq .005$; [4]$P \geq .001$
Mean values in a column with same exponent letter did not vary significantly ($P=.05$)

Control and test rations converted feed (wet and dry weight) at significantly ($P \geq .005$) different rates (Table 3). The wet and dry weight feed conversions of both test rations were superior ($P=.05$) to the Oregon pellet control ration; the salmon meal ration was converted at a better ($P=.05$) rate than the hake meal ration. The superior feed conversion observed for the salmon meal ration was accompanied by a significantly ($P=.05$) better rate of conversion of its protein complement into body protein than observed for either the hake meal ration or the Oregon pellet control. The protein complement of the Oregon pellet control and hake meal rations were converted into body protein at equal ($P=.05$) rates.

At release, the body composition of fish supplied with test rations consisted of slightly higher fat levels and lower moisture and protein contents wet weight; no differences were significant (P≤.05)(Table 4). On a dry weight basis only body ash contents varied significantly (P≥.025). The ash content of fish supplied salmon and hake meal rations was significantly (P=.05) lower than control rations. Blood hematocrit levels and condition factors for fish did not vary (P≤.05) at release. Test rations did produce fish with slightly higher condition factor ratios which reflected their slightly greater body weight and lengths (Table 2) equal (P≤.05) to control fish.

Table 4. Mean body composition, hematocrit and body condition of released fish.

	Ration		
	Control	Salmon meal	Hake meal
Body composition (% wet wt.):			
Moisture[1]	75.59	75.21	75.10
Ash[1]	2.38	2.32	2.37
Fat[1]	5.76	6.45	6.52
Protein[1]	17.04	16.95	16.76
Body composition (% dry wt.):			
Ash[2]	9.77[a]	9.38[b]	9.51[b]
Fat[1]	23.60	25.90	26.19
Protein[1]	69.84	68.41	67.32
Hematocrit (%):	38.1	37.9	37.0
Condition factor: 100,000 x wt(g)/(length-mm)^3 [1]	1.026	1.039	1.035

[1] Mean values in a row did not vary significantly (P≤.05)
[2] Mean values in a row varied significantly (P≥.025)
Mean values in a row with same exponent letter did not vary significantly (P≥.05)

Feed conversion differences strongly suggest that the protein complement of vacuum dried hake meal was inferior to that of salmon meal and no better than that of the control ration under feeding conditions restricted to less than *ad lib*. Fish supplied with the salmon meal ration consumed less protein and more fat than fish receiving the hake meal ration, but its protein complement was converted into more body protein. This would seem to be a direct function of the higher mean fat (9.0 kcal/g)/protein (4.0 kcal/g) caloric ratio in salmon (1.066) over the hake (0.980) ration as computed from the mean ration compositions listed in

Table 5. However, the body fat content of fish supplied with the hake meal ration was slightly greater than observed for the fish fed salmon meal (Table 4). One would have expected a lower body fat level if insufficient dietary fat was supplied to provide optimum protein sparing. It is clear that the protein complement of vacuum dried hake meal was less biologically available for growth of protein based tissues. Protein unavailable for this purpose was converted into body fat stores producing high body fat contents than salmon meal rations even at lower dietary fat levels.

Table 5. Mean composition of ration

	Ration		
	Control	Salmon meal	Hake meal
Percent wet wt.:			
Moisture	28.92±1.08	24.81±1.48	25.20±2.23
Ash	7.77±0.37	6.86±0.12	9.29±0.59
Fat	13.75±0.59	19.29±1.47	17.53±1.21
Protein	36.28±1.33	40.71±1.56	40.25±2.20
Percent dry wt.:			
Ash	10.92±0.54	9.12±0.15	12.43±0.92
Fat	19.27±0.77	25.66±2.00	23.45±1.57
Protein	51.04±1.59	54.16±2.11	53.78±1.60

Superior (P=.05) feed conversions observed for the hake meal test ration over the Oregon pellet control were a direct result of a more efficient deposition of body fat. Fish receiving the hake meal ration were supplied with more dietary fat that was converted more efficiently into body fat (fat consumed/body fat deposited: hake meal =.294; Oregon pellet control =.280). Higher fat contents in the hake meal ration producing an average fat (9.0 kcal/g)/protein (4.0 kcal/g) caloric ratio of 0.980 did not spare protein better than the low fat/protein caloric ratio (0.852) of the Oregon Pellet control even with the apparent disparity in protein quality. Better feed conversions were derived with less feed through the deposition of more body fat.

The relatively poor performance of hake meal protein was difficult to explain and surprising, particularly in comparison to the Oregon pellet control. Fish meals comprising the entire fish are generally regarded as being of equal amino acid composition and availability from a nutritional point of view if not altered by processing. The results of this investigation clearly demonstrate that vacuum dried hake meal is not a superior source of protein for growth.

APPENDIX I
Ration Formulations

	Control ration	Test Rations	
		Hake meal	Salmon meal
Fish meal	28.0(min)[1]	40.0[15]	40.0–42.0[15]
Cottonseed meal	15.0[2]	–	–
Dried whey product	5.0[3]	2.0[3]	2.0[3]
Wheat germ meal	Remainder[4]	11.9[4]	14.9–13.7[4]
Corn distillers solubles	4.0[5]	–	–
Trace mineral premix	0.1[6]	0.1[6]	0.1[6]
Vitamin premix	1.5[7]	1.5[7]	1.5[7]
Spray dried blood meal	–	2.0[8]	2.0[8]
Sodium bentonite	–	2.0	2.0
Spray dried whole fish hydrolysate	–	3.0[9]	3.0[9]
Spray dried carcass waste hydrolysate	–	10.0[10]	10.0[10]
Choline chloride	0.5[11]	0.5[11]	0.5[11]
Pasteurized wet fish	30.0[12]	–	–
Fish oil	6.0–6.75[13]	8.0[14]	4.0–7.2[14]
Water	–	19.0	18.0
Total	100	100	100

[1]Herring meal (min. 67.5% protein) used at no less than 50% of the fish meal in each batch. Anchovy (min. 65% protein), capelin (min. 67% protein), or hake (min. 67% protein) meals may be used as the remainder. Level to supply not less than 21.5% fish meal protein; max. 5% NaCl; 8–12% fat; max 17% ash.

[2]Preprocessed, solvent extracted, min. 48% protein, max 0.055% free gossypol.

[3]Min. 12% protein, max. 6% moisture, max. 10% ash, max. 3% salt

[4]Min. 23% protein and 7% fat

[5]May contain up to 30% "grains" in place of solubles

[6]Gm/lb: Zn, 34.00 ($ZnSO_4$, 84 g/lb); Mn, 34.00 ($MnSO_4$, 94 g/lb); Fe, 4.50 ($FeSO_4 \cdot 7H_2O$, 22.5 g/lb); Cu, 0.70 ($CuSO_4$, 1.75 g/lb); I, 0.23 (KIO_3, 0.38 g/lb); diluted to 1.00 lb with cereal product.

[7]Mg/lb: d-biotin, 18.0; vitamin B_6 535.0 (pyridoxine.HCl, 650 mg); B_{12}, 1.8; vitamin C, 27,000.0 (ascorbic acid); vitamin E, 15,200.0 (water dispersible alpha tocopheryl acetate): folacin, 385.0 (folic acid); Myo-inositol, 4000.0 (not phytate); vitamin K, 180.0 (menadione sodium bisulfite complex, 545 mg); niacin, 5700.0; d-pantothenic acid, 3200.0 (d-calcium pantothenate, 3478 mg or d,l-calcium pantothenate, 6957 mg; riboflavin, 1600.0; thiamine, 715.0 (thiamine mononitrate, 778 mg); dilute to 1.0 lb with cereal product

[8]Spray dried whole blood

APPENDIX I
(Continued)

[9]Spray dried bone-free hydrolysate of whole hake pasteurized at 180°F for $\geq$5.0 min.

[10]Spray dried bone-free hydrolysate of groundfish hydrolysate pasteurized at 180°F for $\geq$5.0 min.

[11]Liquid, 70%

[12]Two or more of the following, with none exceeding 50% of the combination; (1) Salmon or tuna viscera (no heads or gills, with livers); (2) whole herring; (3) bottom fish (whole or fillet scrap); (4) dogfish; (5) whole hake; and (6) whole salmon. Approved enzymes used to aid liquefaction

[13]Herring, salmon, menhaden, dogfish (not more than 3%), or refined tuna oil; stabilized with 0.4% BHA-BHT (1:1); free fatty acids not more than 3%; BHA-BHT must be added at the time of reprocessing if reprocessed oil is used. Special condition when using hake as a wet fish: add 0.5% oil for every 10% hake in total ration.

[14]Herring oil; stabilized with 0.04% BHA-BHT (1:1); free fatty acids not more than 3%.

[15]Vacuum dried

APPENDIX II
Ration Production and Composition

Vacuum Dried Salmon Meal Ration
1982 Brood Coho; Ponds 5 and 14
Oregon Department of Fish and Wildlife Sandy Hatchery

Production			Composition (percent wet wt)				No. Sample
Date	Pellet size	Weight(lb)	Moisture	Ash	Fat	Protein	(n)
06/21/83	3/32"	950	24.57 ±0.29	6.83 ±0.28	20.85 ±0.42	40.88 ±0.54	6
06/30/83	3/32" 1/8"	80 240	27.01 ±0.36	6.71 ±0.05	20.84 ±0.51	38.07 ±0.21	6
07/11/83	3/32"	240	24.82 ±0.06	6.77 ±0.03	20.82 ±0.22	40.69 ±0.20	4
08/11/83	3/32" 1/8"	440 360	23.47 ±0.38	6.91 ±0.05	20.54 ±0.60	40.94 ±0.91	9
08/26/83	1/8"	800	25.47 ±1.08	6.93 ±0.26	19.06 ±0.51	41.05 ±0.80	7
09/01/83	1/8"	480[1]	23.42 ±1.09	6.83 ±0.15	18.96 ±0.82	39.10 ±0.53	7
09/01/83	1/8"	520	25.73 ±1.25	6.79 ±0.09	18.90 ±0.62	41.27 ±0.57	8
10/05/83	1/8"	320	23.89 ±0.25	6.82 ±0.05	18.44 ±0.19	39.43 ±0.86	5
11/18/83	1/8"	1840	26.99 ±0.37	6.83 ±0.16	16.41 ±0.41	42.15 ±0.42	20
03/02/83	1/8"	1040	22.78 ±0.25	7.15 ±0.10	18.08 ±0.16	43.54 ±0.27	14

[1] Medicated ration: 6% TM50

APPENDIX II
(Continued)

Vacuum Dried Hake Meal Ration
1982 Brood Coho; Ponds 7 and 16
Oregon Department of Fish and Wildlife Sandy Hatchery

Production			Composition (percent wet wt)				No. sample
Date	Pellet Size	Weight(lb)	Moisture	Ash	Fat	Protein	n
06/23/83	3/32"	950	28.68 ±0.50	9.22 ±0.02	18.78 ±0.51	36.48 ±0.40	6
06/28/83	3/32"	700	28.32 ±0.27	9.04 ±0.01	16.31 ±0.23	38.21 ±0.12	5
06/30/83	3/32"	900	27.05 ±0.47	10.20 ±0.23	16.14 ±0.41	38.92 ±0.48	6
08/11/83	3/32"	80	22.63 ±0.19	8.87 ±0.02	18.84 ±0.34	43.41 ±0.19	4
08/29/83	1/8"	760	23.67 ±0.38	8.85 ±0.11	19.21 ±0.32	41.78 ±0.34	11
08/29/83	1/8"	480[1]	24.65 ±0.63	8.41 ±0.09	17.59 ±0.34	39.19 ±0.41	6
10/03/83	1/8"	1240	23.67 ±0.44	10.15 ±0.10	17.47 ±0.58	40.66 ±0.47	12
11/21/83	1/8"	1760	23.64 ±0.43	9.44 ±0.10	17.33 ±0.53	41.78 ±0.41	25
03/05/83	1/8"	1320	24.50 ±0.72	9.40 ±0.10	16.07 ±0.52	41.83 ±0.37	19

[1]Medicated ration: 6% TM50

APPENDIX II
(Continued)

Oregon Moist Pellet Control Ration
Representative Sampling of Hatchery Feed Supply
1982 Brood Coho; Ponds 4 and 17
Oregon Department of Fish and Wildlife-Sandy Hatchery

Sample collection date	Pellet size	Composition (percent wet wt.)			
		Moisture	Ash	Fat	Protein
06/13/83	3/32"	30.36	8.02	13.57	36.35
06/13/83	3/32"	29.91	8.12	13.12	36.51
06/13/83	3/32"	30.04	8.08	12.78	36.47
06/15/83	3/32"	29.76	7.77	13.33	35.39
06/23/83	3/32"	26.98	8.32	13.69	39.28
06/30/83	3/32"	28.28	7.71	13.92	36.52
06/30/83	3/32"	29.57	7.64	14.41	36.61
06/30/83	3/32"	27.36	7.71	15.22	36.66
07/18/83	3/32"	28.27	7.86	13.79	36.72
07/18/83	3/32"	28.53	7.83	13.90	36.61
Mean		28.91	7.91	13.77	36.71
S.D.		1.18	0.22	0.68	0.98
10/04/83	1/8"	29.88	7.05	13.40	34.57
11/02/83	1/8"	29.51	7.99	13.82	32.77
11/15/83	1/8"	27.90	7.61	14.12	37.77
11/15/83	1/8"	28.48	7.02	13.46	36.74
Mean		28.94	7.42	13.70	35.46
S.D.		0.91	0.47	0.33	2.24

APPENDIX III

Computation of Feed Consumed

Vacuum Dried Salmon Meal Ration
1982 Brood Coho; Ponds 5 and 14
Oregon Department of Fish and Wildlife Sandy Hatchery

Time period	Pellet size	Feed Consumed Pond 5 (lb)				Feed Consumed Pond 14 (lb)			
		Wet wt.	Dry wt.	Protein	Fat	Wet wt.	Dry wt	Protein	Fat
06/27-30/83	3/32"	40	30.2	16.3	8.3	40	30.2	16.3	8.3
07/01-31/83	3/32"	364	274.6	148.8	75.9	364	274.6	148.8	75.9
08/01-31/83	3/32"	434	328.3	176.2	89.8	434	328.3	176.2	89.8
09/01	3/32"	15	11.5	6.1	3.1	15	11.3	6.1	3.1
09/02-17/83	1/8"	240	183.8	93.8	45.5	240	183.8	93.8	45.5
09/18	3/32"	7	5.4	1.4	2.9	7	5.4	1.4	2.9
09/19-30/83	1/8"	201	149.6	78.8	41.6	201	149.6	78.8	41.6
10/01-31/83	1/8"	430	322.5	176.4	83.4	416	312.0	170.7	80.7
11/01-30/83	1/8"	262	194.8	107.9	49.6	284	211.1	117.0	53.8
12/01-20/83	1/8"	200	151.1	80.0	37.2	200	151.1	80.0	37.2
12/30-31/83	1/8"	10	7.6	3.9	1.8	10	7.6	3.9	1.8
01/01-15/84	1/8"	146	107.0	61.2	24.2	146	107.0	61.2	24.2
01/16-31/84	1/8"	121	88.3	51.0	19.9	121	88.3	51.0	19.9
02/01-29/84	1/8"	299	218.3	126.0	49.1	299	218.3	126.0	49.1
03/01-31/84	1/8"	331	241.7	139.5	54.3	331	241.7	139.5	54.3
04/01-29/84	1/8"	414	316.7	179.2	73.6	382	291.9	165.3	67.9
Total:		3514	2631.4	1446.5	660.2	3490	2612.2	1436.0	656.0

APPENDIX III
(Continued)

Vacuum Dried Hake Meal Ration
1982 Brood Coho; Ponds 7 and 16
Oregon Department of Fish and Wildlife Sandy Hatchery

Time	Pellet	Feed Consumed Pond 7 (lb)				Feed Consumed Pond 16 (lb)			
period	size	Wet wt.	Dry wt.	Protein	Fat	Wet wt.	Dry wt	Protein	Fat
06/27-30/83	3/32"	40	28.5	14.6	7.5	40	28.5	14.6	7.5
07/01-31/83	3/32"	364	260.7	138.0	60.8	364	260.7	138.0	60.8
08/01-31/83	3/32"	454	330.6	176.4	73.3	454	330.6	176.4	73.3
09/01	3/32"	15	10.9	5.8	2.4	15	10.9	5.8	2.4
09/02-17/83	1/8"	240	180.8	94.0	42.2	240	180.8	94.0	42.2
09/15-19/83	3/32"	68	51.4	28.3	12.1	66	49.9	27.4	11.7
09/18-30/83	1/8"	214	163.3	89.4	41.1	216	164.9	90.2	41.5
10/01-31/83	1/8"	430	328.2	176.7	78.0	416	317.5	171.0	75.5
11/01-30/83	1/8"	270	206.1	109.8	47.2	284	216.8	115.5	49.6
12/01-20/83	1/8"	200	152.7	82.6	34.8	200	152.7	82.6	34.8
12/30-31/83	1/8"	10	7.6	4.2	1.7	10	7.6	4.2	1.7
01/01-15/84	1/8"	146	111.5	61.0	25.3	146	111.5	61.0	25.3
01/21-31/84	1/8"	121	92.4	50.5	21.0	121	92.4	50.5	21.0
02/01-29/84	1/8"	299	228.3	124.9	51.8	299	228.3	124.9	51.8
03/01-31/84	1/8"	356	270.4	148.8	59.6	356	270.4	148.8	59.6
04/01-29/84	1/8"	444	335.2	185.7	71.3	444	335.2	185.7	71.3
Total:		3671	2758.6	1490.7	630.1	3671	2758.7	1490.6	630.0

Oregon Moist Pellet Control Ration
1982 Brood Coho; Ponds 4 and 17
Oregon Department of Fish and Wildlife Sandy Hatchery

Pellet	Feed Consumed Pond 4 (lb)				Feed Consumed Pond 17 (lb)			
size	Wet wt.	Dry wt.	Protein	Fat	Wet wt.	Dry wt	Protein	Fat
3/32"	949	674.6	348.4	130.7	941	668.9	345.4	129.6
1/8"	3375	2398.3	1196.8	462.4	3359	2386.9	1191.1	460.2
Total	4324	3072.9	1545.2	593.1	4300	3055.8	1536.5	589.8

APPENDIX IV
SUMMARY OF GROWTH RESPONSE PARAMETERS
1982 BROOD COHO
OREGON DEPARTMENT OF FISH AND WILDLIFE SANDY HATCHERY

Ration		Control Ration		Salmon Meal Ration		Hake Meal Ration	
Pond		4	17	5	14	7	16
Binary code		7-29/31	7-29/6	7/29/12	7-29/9	7-29/10	7-29/7
Initial wt.	kg:	245.8	249.9	250.8	253.1	257.2	248.1
of fish	lb:	542	551	553	558	567	547
Initial No. of fish		58577	58452	58653	58610	58436	58562
No. of tagged fish released		25763	26983	25250	26573	26654	26095
Total No. of fish released		57913	58069	57594	58100	57772	57691
Mortality (No.)		664	386	1063	574	669	875
Total wt. of	kg:	1555.4	1546.2	1550.7	1568.2	1525.9	1507.8
fish released	lb:	3429.1	3408.8	3418.7	3457.3	3364.0	3324.1
Fish length	No.:	655	820	756	779	764	853
(mm)	mean:	138.0	137.2	137.0	137.8	136.5	136.3
	S.D.:	6.2	7.2	6.5	7.3	7.5	7.0
Hematocrit (%)	No.:	12	12	12	12	12	12
	mean:	36.6	39.6	36.7	39.1	35.3	38.7
	S.D.:	3.1	2.8	4.2	3.3	3.6	4.4
Feed	kg:	1961.3	1950.4	1593.9	1583.0	1665.1	1665.1
(wet wt.)	lb:	4324	4300.0	3514	3490	3671	3671
Feed	kg:	1393.8	1386.1	1193.6	1184.8	1251.3	1251.3
(dry wt.)	lb:	3072.9	3055.8	2631.4	2612.2	2758.6	2758.7
Feed	kg:	700.9	696.9	656.1	651.3	676.2	676.1
protein	lb:	1545.2	1536.5	1446.5	1436.0	1490.7	1490.6
Feed	kg:	269.0	267.5	299.5	297.5	285.8	285.8
fat	lb:	593.1	589.8	660.2	656.0	630.1	630.0
Body wt.	kg:	1309.6	1296.3	1299.9	1315.1	1268.7	1259.7
gain	lb:	2887.1	2857.8	2865.7	2899.3	2797.0	2777.1
Body protein	kg:	225.1	218.9	221.3	222.0	213.6	210.1
gain	lb:	496.2	482.7	488.0	489.4	471.0	463.2
Body fat	kg:	75.0	75.2	83.0	84.8	85.4	79.5
gain	lb:	165.4	165.7	183.1	187.0	188.2	175.2

APPENDIX V

SUMMARY OF COMPUTED GROWTH RESPONSE PARAMETERS

1982 BROOD COHO

OREGON DEPARTMENT OF FISH AND WILDLIFE SANDY HATCHERY

Ration		Control Ration		Salmon Meal Ration		Hake Meal Ration	
Pond		4	17	5	14	7	16
Binary code		7-29/31	7-29/6	7/29/12	7-29/9	7-29/10	7-29/7
Average Initial	g/fish:	4.197	4.276	4.277	4.318	4.401	4.237
fish size	fish/kg:	238.26	233.87	233.83	231.56	227.21	236.03
	fish/lb:	108.07	106.08	106.06	105.03	103.06	107.06
Average release	g/fish:	26.858	26.627	26.925	26.991	26.412	26.135
fish size	fish/kg:	37.23	37.55	37.14	37.05	37.86	38.26
	fish/lb:	16.89	17.03	16.85	16.80	17.17	17.35
Feed (wet.wt.)/ wt. gain		1.4977	1.5046	1.2262	1.2037	1.3124	1.3219
Feed (dry wt)/ wt. gain		1.0643	1.0693	0.9182	0.9010	0.9863	0.9934
Feed protein/ protein gain		3.1141	3.1831	2.9641	2.9342	3.1650	3.2180
Feed fat/ fat gain		3.5858	3.5594	3.6056	3.5080	3.3480	3.5959
Condition factor: 100,000 x wt.(g)/ length (mm)^3		1.0219	1.0310	1.0471	1.0314	1.0385	1.0321
Body fat (9.0 kcal/g)/ protein (4.0 kcal/g) ratio		.750	.773	.844	.860	.899	.851

APPENDIX VI
BODY COMPOSITION OF RELEASED FISH
1982 BROOD COHO
OREGON DEPARTMENT OF FISH AND WILDLIFE SANDY HATCHERY

		OP2 Control		Salmon Meal Ration		Hake Meal Ration	
Component	Rep	Pond 4	Pond 17	Pond 5	Pond 14	Pond 7	Pond 16
Moisture	1	75.70	76.07	75.28	75.17	74.74	75.49
(% wet wt.)	2	75.34	75.19	75.29	75.38	75.21	75.40
	3	75.35	75.90	75.46	74.73	74.73	75.08
	$\bar{x}$	75.46	75.72	75.34	75.09	74.89	75.32
	SD	0.20	0.47	0.10	0.33	0.27	0.21
Ash	1	2.39	2.38	2.28	2.35	2.39	2.35
(% wet wt.)	2	2.39	2.33	2.32	2.35	2.38	2.37
	3	2.42	2.37	2.33	2.32	2.36	2.35
	$\bar{x}$	2.40	2.36	2.31	2.34	2.38	2.36
	SD	0.02	0.03	0.03	0.02	0.01	0.01
Fat	1	5.48	5.71	6.71	6.26	6.69	6.17
(% wet wt.)	2	5.94	6.11	6.38	6.23	6.46	6.24
	3	5.76	5.57	6.08	6.87	7.05	6.53
	$\bar{x}$	5.73	5.80	6.39	6.45	6.73	6.31
	SD	0.23	0.28	0.31	0.36	0.30	0.19
Protein	1	17.00	16.92	16.80	16.99	17.00	16.65
(% wet wt.)	2	17.16	16.58	17.19	16.64	16.43	16.70
	3	17.42	17.18	17.09	17.01	17.09	16.68
	$\bar{x}$	17.19	16.89	17.03	16.88	16.84	16.68
	SD	0.21	0.30	0.20	0.21	0.36	0.02
Ash	1	9.83	9.95	9.22	9.46	9.46	9.59
(% dry wt.)	2	9.69	9.39	9.39	9.54	9.60	9.63
	3	9.82	9.83	9.49	9.18	9.34	9.43
	$\bar{x}$	9.78	9.72	9.37	9.39	9.47	9.55
	SD	0.08	0.29	0.14	0.19	0.13	0.10
Fat	1	22.55	23.86	27.14	25.21	26.48	25.17
(% dry wt.)	2	24.09	24.63	25.82	25.30	26.06	25.36
	3	23.37	23.11	24.77	27.19	27.90	26.20
	$\bar{x}$	23.34	23.87	25.91	25.90	26.81	25.58
	SD	0.77	0.76	1.18	1.11	0.96	0.55
Protein	1	69.96	70.71	67.96	68.42	67.30	67.93
(% dry wt.)	2	69.59	66.83	69.57	67.59	66.28	67.89
	3	70.67	71.29	69.64	67.31	67.63	66.93
	$\bar{x}$	70.07	69.61	69.06	67.77	67.07	67.58
	SD	0.55	2.42	0.95	0.58	0.70	0.57

ADDENDUM D

DEVELOPMENT OF RATIONS FOR THE ENHANCED SURVIVAL OF SALMON

Bonneville Power Administration Project 83-363

Influence of Ration on the Survival of Fall Chinook Salmon I. 1983 Brood Fall Chinook Salmon Rearing Investigation; Oregon Department of Fish and Wildlife Bonneville Hatchery

Introduction

The survival of hatchery salmonids is dependent upon a number of factors including time of release, natural food abundance, fish size and the health and/or quality of smolts. These factors determine survival from predation, ability to acquire sustainable nutrients under natural conditions, vitality to surmount man made impediments to seaward migration and adaptation to a sea water environment. It is believed that the nutritional characteristics of feed utilized to rear hatchery salmonids play an important role in how smolts overcome impediments to their survival. Of primary nutritional importance, is the quality of the protein complement of the ration.

This investigation was designed to evaluate the rearing of fall chinook salmon with rations containing a high quality protein complement and to release tagged fish for a future measurement of the effect of ration regimes on survival. Released tagged 1983 brood fall chinook salmon represent the first replicate in an evaluation of the influence of ration on survival. The survival of this brood of fish will be evaluated from tags recovered from the fishery and at the hatchery during 1985-88.

Husbandry Protocol

Pond Stocking

Fish (at an average size of 0.374 g/fish) (1983-brood fall chinook; tule stock) were distributed into four ponds in battery C at Bonneville Hatchery at approximamtely 600,000 fish/pond (Appendix IV) on Dec 29, 1983. The ponds in battery C were the rectangular type, supplied with well water and equipped with Garon automatic feeders. At 241.8-263.4 fish/lb (Appendix IV), the fish populations in each pond was thinned to 274560-277242 (Appendix IV) on February 24, 1984.

Rearing Schedule

Feeding of control and test rations was initiated on December 29, 1983. The determined weight and number of fish/pond at initiation and after thinning are listed in Appendix IV with computed average fish weights. Fish were reared under hatchery conditions and released on May 8, 1984. The total number of fish released is listed in Appendix IV.

Rations

Duplicate ponds were fed (1) Oregon pellet feed system rations which served as a control and (2) a test ration system containing spray dried whole salmon hydrolysate (1/32" size pellets) and vacuum dried whole salmon meal, (3/64-3/32" size pellets). Both control and test fish were started on closed formulation commercial starter ration (Biodiet Starter #2). A summary of the Oregon pellet feed system specifications (Oregon Department of Fish and Wildlife Specifications, July 1983) and the formulation of the two test rations is listed in Appendix I.

Rations composing the control Oregon pellet feed system were obtained from the normal Bonneville Hatchery feed supply. Test rations were formulated and prepared at the Oregon State University Seafoods Laboratory utilizing vacuum and spray dried meals produced by a commercial firm according to requested specifications.

Control rations composition were assessed by sampling the entire feed supply of the hatchery by production date when feasible. Test rations were sampled for composition determination by lot during production. Ration composition information on control and test rations is listed in Appendix II.

Feeding

All lots of fish were on a demand basis. The quantity of feed supplied all ponds was recorded and is summarized in Appendix IV. Computation of feed (dry wt), feed protein and feed fat consumed by control fish was based upon the mean composition of starter ration and 1/32", 3/64", 1/16", and 3/32" pelletized rations. These computations for the test ration were based upon the quantity and composition of the actual production lots fed. Computations are listed in Appendix III.

Fish Marking

Fish were injected with destinctive coded wire tags and marked with an adipose fin clip between April 17-27, 1984 at a rate that yielded a release of at least 75,000 fish/pond. The actual number of tagged fish released/pond based upon tag retention evaluations before release is listed on Appendix IV.

Characterization of Released Fish

Just prior to release, triplicate samples of fish from each pond were obtained for proximate analysis and average blood hematocrit levels and fork lengths were determined. The proximate compositions of fish, blood hematocrit levels and fork lengths with numbers of fish involved in these estimates of pond populations are listed in Appendix IV.

Rearing Results

Fish in numbers listed in Table 1 were reared on test rations from December 29, 1983 to May 8, 1984. Tagged fish (injected with coded wire tags and marked with an adipose fin clip between May 17 and 27, 1984) composed approximately 29% of the population released. Mortality for the fish supplied the control ration system averaged 5.10% for the period from December 29 through February 23, 1984 and 0.68% from February 24 through May 8, 1984. During the same time periods, mortalities for fish supplied salmon meal ration were 3.18 and 0.53%, respectively. Although mortalities for fish supplied salmon meal ration were somewhat lower than those observed for the control ration system, the mortality of the two populations did not vary significantly ($P \leq .05$).

Table 1. Number of fish reared and mortality

Ration:	Oregon Pellet Control			Salmon Meal Ration		
Pond:	C-3	C-4		C-5	C-6	
Binary code:	7-31/20	7-31/21	Mean	7-31/22	7-31/23	Mean
Initial No. fish	608355	611584	-	603159	607496	-
No. fish 2/23/83	574746	582941	-	580162	591966	-
Mortality (No.)	33609	28643	-	22997	15530	-
Mortality (%)[1]	5.52	4.68	5.10	3.81	2.56	3.18
No. fish 2/24/84	274560	275058	-	277242	277134	-
No. tagged fish released	80348	80046	-	80138	81282	-
Total No. fish released	272648	273216	-	275853	275607	-
Mortality (No.)	1912	1842	-	1382	1527	-
Mortality (%)[1]	0.70	0.67	0.68	0.50	0.55	0.53

[1]Mean values in a row did not vary significantly $P \leq .05$

Fish supplied the control ration system on a demand basis were reared from an average of 0.374 g/fish to 6.042 g/fish with an average fork length of 82.5 mm (Table 2). Equal size fish (0.374 g/fish) supplied the vacuum dried salmon meal test ration were reared to an average weight of 7.237 g/fish and a length of 87.0 mm. While the average weight and length of test fish at release was 119.8% and 105.4%, respectively, of control fish, the limited replication of experimental treatments allowed did not yield a significant difference ($P \leq .05$) for either fish weight or length.

Table 2. Weight of fish reared and fish size

Ration:	Oregon Pellet Control			Salmon Meal Ration		
Pond:	C-3	C-4		C-5	C-6	
Binary code:	7-31/20	7-31/21	Mean	7-31/22	7-31/23	Mean
Initial wt. of fish:						
Total (kg)	227.5	228.7	-	225.6	227.2	-
Total (lb)	501.6	504.3	-	497.3	500.9	-
G/fish[1]	0.374	0.374	0.374	0.374	0.374	0.374
Fish/lb	1212.8	1212.8	-	1212.8	1212.8	-
Wt. of fish 2/23/84:						
Total (kg)	1001.8	1023.6	-	1101.1	1101.0	-
Total (lb)	2208.5	2256.7	-	2427.6	2427.4	-
G/fish[1]	1.743	1.756	1.749	1.898	1.860	1.879
Fish/lb	260.2	258.3	-	239.0	243.9	-
Wt. of fish 2/24/84:						
Total (kg)	472.8	481.9	-	520.1	508.8	-
Total (lb)	1042.3	1062.4	-	1146.6	1121.7	-
G/fish[1]	1.722	1.752	1.737	1.876	1.836	1.856
Fish/lb	263.4	258.9	-	241.8	247.0	-
Wt. of fish at release:						
Total (kg)	1743.8	1554.3	-	2137.6	1853.7	-
Total (lb)	3844.5	3426.7	-	4712.6	4086.8	-
G/fish[1]	6.396	5.689	6.042	7.749	6.726	7.237
Fish/lb	70.9	79.7	-	58.5	67.4	-
Length at release (mm)						
Mean[1]	83.3	81.7	82.5	88.5	85.6	87.0
S.D.	7.26	7.01		6.07	6.88	

[1]Mean values in a row did not vary significantly $P \leq .05$

Control fish consumed slightly more (NS $P \leq .05$) feed (wet and dry wt.) (Table 3), but the more protein and fat energy rich test ration regime (Table 4) supplied slightly more protein and fat (Appendix IV). Test rations were converted (wet, dry and protein) in a somewhat (NS $P \leq .05$) superior manner (Table 3). The quantity of test ration feed (wet, dry) required to produce a unit of body weight was 76.2 and 80.2% of the control, respectively. The quantity of test ration protein required to produce a unit of body protein gain was 90.6% of the control.

Table 3. Feed consumption and conversion

Ration:	Oregon Pellet Control			Salmon Meal Ration		
Pond:	C-3	C-4		C-5	C-6	
Binary code:	7-31/20	7-31/21	Mean	7-31/22	7-31/23	Mean
Feed consumption (wet wt.)(kg):						
12/29/83-2/24/84[2]	745.7	776.5	761.1	715.5	737.8	726.6
	(1644)[1]	(1712)		(1577.5)	(1626.5)	
2/25-5/6/84[2]	1773.5	1619.3	1696.4	1635.2	1419.7	1527.4
	(3910)	(3570)		(3605)	(3130)	
12/29/83-5/6/84[2]	2519.2	2395.8	2457.5	2350.7	2157.5	2254.1
	(5554)	(5282)		(5182.5)	(4756.5)	
Feed consumption (dry wt)(kg):						
12/29/83-2/24/84[2]	542.1	564.8	553.4	549.9	566.9	558.4
	(1195.1)	(1245.3)		(1212.4)	(1249.8)	
2/25-5/6/84[2]	1278.4	1166.7	1222.5	1241.0	1077.2	1159.1
	(2818.4)	(2572.1)		(2736.0)	(2374.9)	
12/29/83-5/6/84[2]	2519.9	2395.8	2457.5	2350.7	2157.5	2254.1
	(5554)	(5282)		(5182.5)	(4756.5)	
Feed (wet wt.)/gain:						
12/29/83-2/24/84[2]	0.96	0.98	0.97	0.82	0.84	0.83
2/25/84-5/6/84[2]	1.39	1.51	1.45	1.01	1.06	1.03
12/29/83-5/6/84[2]	1.23	1.28	1.26	0.94	0.97	0.96
Feed (dry wt.)/gain:						
12/29/83-2/24/84[2]	0.70	0.71	0.70	0.62	0.65	0.64
2/25-5/6/84[2]	1.01	1.09	1.05	0.77	0.80	0.78
12/29/83-5/6/84[2]	0.89	0.92	0.91	0.72	0.74	0.73
Feed protein/protein gain:						
12/29/83-5/6/842	3.03	3.17	3.10	2.74	2.88	2.81

[1]( ) = lb
[2]Mean values in a row did not vary significantly ($P \leq .05$)

Table 4. Mean composition of rations

	Ration			
	Oregon Pellet Control		Salmon Meal	
	1/32"	3/64-3/32"	1/32"	3/64-3/32
Percent wet wt.:				
Moisture	25.32 ±1.09	28.17 ±1.63	20.44 ±.44	23.74± .86
Ash	7.77 ± .31	8.01 ± .91	4.84 ±.15	7.26± .63
Fat	17.00 ± .57	13.61 ±1.39	22.38 ±.44	18.43± .94
Protein	42.01 ±1.55	36.73 ±1.70	50.97 ±.42	43.11±1.37
Percent dry wt.:				
Ash	10.40 ± .28	11.15 ±1.17	6.24 ±.19	9.52± .80
Fat	22.78 ±1.09	18.92 ±1.55	28.85 ±.45	24.17±1.28
Protein	56.27 ±2.68	51.13 ±1.85	65.72 ±.47	56.49±1.89

Fish supplied the test ration possessed a somewhat different general body condition at release (Table 5). While the proximate body composition (moisture, ash, fat and protein) did not vary significantly ($P \leq .05$) at release, the test ration produced a body composition slightly higher in fat and lower in moisture and protein than control fish. This was a general reflection of the relatively more nutrient rich nature of the test ration. Blood hematocrit levels for fish supplied the test ration were 112.7% of those observed for the control ration, but were not significantly ($P \leq .05$) higher within this experimental design. The test ration produced fish with a somewhat better condition factor (NS $P \leq .05$). Better "condition" was achieved with both a greater fork length and body weight (Table 2)

Table 5. Mean body compositions, hematocrit and body condition of released fish

	Ration	
	Oregon Pellet Control	Salmon Meal
Body composition (% wet wt)		
Moisture[1]	76.98	75.64
Ash[1]	2.03	1.99
Fat[1]	6.62	7.92
Protein[1]	15.15	15.11
Body composition (% dry wt.)		
Ash[1]	8.83	8.16
Fat[1]	28.74	32.51
Protein[1]	65.83	62.05
Hematocrit (%)[1]	32.70	36.70
Condition factor:[1] 100,000 x wt(g)/(length - mm)^3	1.075	1.179

Mean values in a row did not vary significantly ($P \leq .05$)

The demand feeding of the test ration which relied on high quality vacuum dried salmon meal produced fish of somewhat different characteristics than the control ration at release. Although these differences were not significant ($P<.05$) within the limited replication of the experimental design, the characteristics of test fish appeared to have a better advantage for survival. The more nutrient rich test ration produced fish of greater weight and length yielding a superior condition factor, more body fat energy stores and a better blood hematocrit level. This better growth response was achieved with less feed through the better conversion of more basic nutrients (dietary protein and fat).

APPENDIX I
RATION FORMULATIONS

	Control Ration		Salmon Meal Rations	
Pellet size:	1/32"[21]	3/64-3/32"	1/32"	3/64-3/32"
Spray dried whole salmon hydrolysate	-	-	51.0[16]	
Fish meal	43.0[17]	28.0(min)[1]	-	40.0[15]
Cottonseed meal	-	15.0[2]	-	-
Dried whey product[3]	4.0	5.0	-	2.0
Wheat germ meal[4]	Remainder	Remainder	-	14.4-11.9
Corn distillers solubles[5]	-	4.0	-	-
Trace mineral premix[6]	0.1	0.1	0.1	0.1
Vitamin premix[7]	1.5	1.5	2.0	1.5
Spray dried blood meal[8]	-	-	5.4	2.0
Sodium bentonite	-	-	2.0	2.0
Spray dried whole fish hydrolysate[9]	-	-	-	3.0[9]
Spray dried carcass waste hydrolysate[10]	-	-	10.0	10.0
Choline chloride[11]	0.5	0.5	0.5	0.5
Pasteurized wet fish	25.0-28.0[12,18]	30.0[12]	-	-
Fish oil	7.0[13,19]	6.0-6.75[13]	9.0[14]	6.5-9.0[14]
Spray dried fish[20]	7.0	-	-	-
Water	-	-	20.0	18.0-19.0
Total	100	100	100	100

[1]Herring meal (min. 67.5% protein) used at no less than 50% of the fish meal in each batch. Anchovy (min. 65% protein), capelin (min. 67% protein), or hake (min. 67% protein) meals may be used as the remainder. Level to supply not less than 21.5% fish meal protein; max. 5% NaCl; 8-12% fat; max 17% ash.

[2]Preprocessed, solvent extracted, min. 48% protein, max 0.055% free gossypol.

[3]Min. 12% protein, max. 6% moisture, max. 10% ash, max. 3% salt

[4]Min. 23% protein and 7% fat

[5]May contain up to 30% "grains" in place of solubles

[6]Gm/lb: Zn, 34.00 ($ZnSO_4$, 84 g/lb); Mn, 34.00 ($MnSO_4$, 94 g/lb); Fe, 4.50 ($FeSO_4 \cdot 7H_2O$, 22.5 g/lb); Cu, 0.70 ($CuSO_4$, 1.75 g/lb); I, 0.23 (KIO_3, 0.38 g/lb); diluted to 1.00 lb with cereal product.

[7]Mg/lb: d-biotin, 18.0; vitamin B_6 535.0 (pyridoxine.HCl, 650 mg); B_{12}, 1.8; vitamin C, 27,000.0 (ascorbic acid); vitamin E, 15,200.0 (water dispersible alpha tocopheryl acetate): folacin, 385.0 (folic acid); Myo-inositol, 4000.0 (not phytate); vitamin K, 180.0 (menadione sodium bisulfite complex, 545 mg); niacin, 5700.0; d-pantothenic acid, 3200.0 (d-calcium pantothenate, 3478 mg or d,l-calcium pantothenate, 6957 mg; riboflavin, 1600.0; thiamine, 715.0 (thiamine mononitrate, 778 mg); dilute to 1.0 lb with cereal product

[8]Spray dried whole blood

[9]Spray dried bone-free hydrolysate of whole hake pasteurized at 180°F for ≥5.0 min.

[10]Spray dried bone-free hydrolysate of groundfish hydrolysate pasteurized at 180°F for ≥ 5.0 min.

[11]Liquid, 70%

[12]Two or more of the following, with none exceeding 50% of the combination; (1) Salmon or tuna viscera (no heads or gills, with livers); (2) whole herring; (3) bottom fish (whole or fillet scrap); (4) dogfish; (5) whole hake; and (6) whole salmon. Approved enzymes used to aid liquefaction. Dogfish and bottomfish carcass waste not allowed for 1/32" pellet sizes.

[13]Herring, salmon, menhaden, dogfish (not more than 3%), or refined tuna oil; stabilized with 0.4% BHA-BHT (1:1); free fatty acids not more than 3%; BHA-BHT must be added at the time of reprocessing if reprocessed oil is used. Special condition when using hake as a wet fish: add 0.5% oil for every 10% hake in total ration.

[14]Herring oil; stabilized with 0.04% BHA-BHT (1:1); free fatty acids not more than 3%.

[15]Vacuum dried

[16]Spray dried bone-free hydrolysate of whole salmon pasteurized at 180°F for ≥5.0 min.

[17]Whole herring or salmon meal; min 70% protein; 8-12% fat; max 3% NaCl; max 17% ash.

[18]Level of wet fish dependent on need to obtain desirable pellet qualities.

[19]The total dietary fat must be at least 22% (dry wt.) with the level of fish oil increased if needed to attain the required level of fat.

[20]Min. 48% protein; max 7% ash.

[21]The total dietary protein supplied by fish meal, spray-dried fish, and wet fish must be at least 36.5%; with fish meal increased, if needed; to attain the required level of protein.

APPENDIX II
RATION PRODUCTION AND CONSUMPTION

Vacuum Dried Salmon Meal Ration
1983 Brood Fall Chinook; Ponds C5 and C6
Oregon Department of Fish and Wildlife Bonneville Hatchery

	Production		Composition (percent wet wt)				No
Date	Pellet size	Weight(lb)	Moisture	Ash	Fat	Protein	samples(n)
12/19/83	1/32	1080	22.44 ±0.44	4.84 ±0.15	22.38 ±0.44	50.97 ±0.42	14
01/09/84	3/64	1700	23.85 ±0.41	7.68 ±0.11	17.86 ±0.28	43.53 ±0.49	23
01/10/84	1/16	800	24.20 ±0.14	7.75 ±0.08	18.52 ±0.13	42.99 ±0.26	11
01/25/84	1/32 1/16	480 50	22.93 ±0.15	8.75 ±0.05	17.73 ±0.16	44.52 ±0.17	7
02/28/84	1/16 3/32	1250 350	23.35 ±0.49	6.94 ±0.41	18.18 ±0.19	43.47 ±0.36	23
03/03/84	3/32	200	22.13 ±0.19	7.17 ±0.03	18.36 ±0.21	43.64 ±0.17	3
03/09/84	3/32	1400	24.11 ±0.53	6.59 ±0.05	17.21 ±0.21	44.57 ±1.05	20
04/03/84	3/32	1450	25.39 ±0.48	6.85 ±0.06	18.07 ±0.40	44.31 ±0.92	18
04/04/84	3/32	350	23.44 ±0.39	7.02 ±0.03	18.26 ±0.23	42.30 ±0.61	6
04/25/84	3/32	900 450	24.12 ±0.20	6.99 ±0.06	20.15 ±0.09	40.77 ±0.26	9
05/03/84	3/32	800	23.87 ±0.51	6.91 ±0.07	19.98 ±0.38	40.98 ±0.27	10

APPENDIX II
(Continued)

Oregon Pellet Control Ration
Representative Sampling of Hatchery Feed Supply
1983 Brood Fall Chinook, Ponds C3 and C4
Oregon Department of Fish and Wildlife Bonneville Hatchery

Sample collection date	Pellet size	Composition (percent wet wt.)			
		Moisture	Ash	Fat	Protein
01/13/83	Starter	19.51	9.31	17.64	46.67
01/13/84	1/32	26.20	7.45	17.27	43.79
01/31/84	1/32	24.90	8.08	16.34	41.28
01/20/84	1/32	25.67	7.78	17.40	40.95
	Mean	25.32	7.77	17.00	42.01
	S.D.	1.09	0.31	0.57	1.55
02/17/84	3/64	28.86	6.72	14.21	35.51
03/01/84	1/16	28.32	7.49	12.88	37.45
03/09/84	1/16	29.69	7.03	11.86	37.58
03/21/84	1/16	29.21	9.32	12.09	37.92
	Mean	29.07	7.95	12.27	37.65
	S.D.	0.69	1.21	0.54	0.24
03/30/84	3/32	26.67	8.66	14.58	37.92
04/13/84	3/32	24.80	8.90	16.12	39.39
04/23/84	3/32	28.69	8.02	13.68	34.65
04/23/84	3/32	29.14	7.98	13.47	34.55
	Mean	27.32	8.39	14.46	36.63
	S.D.	1.99	0.46	1.20	2.42

APPENDIX III
COMPUTATION OF FEED CONSUMED

Oregon Pellet Control Ration
1983 Brood Fall Chinook; Ponds C-3 and C-4
Oregon Department of Fish and Wildlife Bonneville Hatchery

Time period	Pellet size	Feed Consumed Pond C-3 (lb) Wet wt	Dry wt	Protein	Fat	Feed Consumed Pond C-4(lb) Wet wt.	Dry wt	Protein	Fat
12/29-1/1	Starter	52	41.8	24.3	9.2	52	41.8	24.3	9.2
1/4-31	1/32	587	438.3	246.6	99.8	640	477.9	268.9	108.8
2/1-24	3/64	1005	715.0	356.9	142.8	1020	725.6	362.2	144.9
Subtotal		1644	1195.1	627.8	251.8	1712	1245.3	655.4	262.9
2/25-3/26	1/16	1320	936.3	497.0	162.0	1290	915.0	485.7	158.3
3/27-5/6	3/32	2590	1882.4	948.7	374.5	2280	1657.1	835.2	329.7
Subtotal		3910	2818.4	1445.7	536.5	3570	2572.1	1320.9	488.0
Total		5554	4013.5	2073.5	788.3	5282	3817.4	1976.3	750.9

Salmon Meal Ration
1983 Brood Fall Chinook; Ponds C-5 and C-6
Oregon Department of Fish and Wildlife Bonneville Hatchery

Time period	Pellet size	Feed Consumption Pond C-5(lb) Wet wt.	Dry wt.	Protein	Fat	Feed Consumption Pond C-6(lb) Wet wt.	Dry wt.	Protein	Fat
12/29-1/1	Starter	52	41.8	24.3	9.2	52	41.8	24.3	9.2
01/04-31	1/32	690.5	534.8	342.2	146.9	699.5	541.7	346.2	149.1
02/01-24	3/64	835	635.8	363.5	149.1	875	666.3	380.9	156.3
Subtotal		1577.5	1212.4	730.0	305.2	1626.5	1249.8	751.4	314.6
02/25-3/26	1/16	1135	866.4	491.7	207.6	1015	774.7	439.6	185.8
03/22-5/6	3/32	2470	1869.6	1069.6	453.5	2115	1600.2	924.8	382.0
Subtotal		3605	2736.0	1561.3	661.1	3130	2374.9	1364.4	567.8
Total		5182.5	3948.4	2291.3	966.3	4756.5	3624.7	2115.8	882.4

APPENDIX IV
SUMMARY OF GROWTH RESPONSE PARAMETERS
1983 BROOD FALL CHINOOK
OREGON DEPARTMENT OF FISH AND WILDLIFE
BONNEVILLE HATCHERY

Ration:		Oregon Pellet Control		Salmon Meal Ration	
Pond:		C-3	C-4	C-5	C-6
Binary code:		7-31/20	7-31/21	7-31/22	7-31/23
Initial wt. of fish (12/29/83)	(lb):	501.6	504.3	497.3	500.9
	(kg):	227.5	228.7	225.6	227.2
Initial No. of fish (12/29/83):		608355	611584	603159	607496
Initial size of fish (12/29/83)	(g/fish):	0.374	0.374	0.374	0.374
	(fish/lb):	1212.8	1212.8	1212.8	1212.8
	(fish/kg):	2673.8	2673.8	2673.8	2673.8
Wt. of fish (2/23/84)	(lb):	2208.5	2256.7	2427.6	2427.4
	(kg):	1001.8	1023.6	1101.1	1101.1
No. fish on (2/23/83):		574746	582941	580162	591966
Fish size (02/23/84)	(g/fish):	1.743	1.756	1.898	1.860
	(fish/lb):	260.2	258.3	239.0	243.9
	(fish/kg):	573.7	569.5	526.9	537.6
Wt. of fish (2/24/84)(split)	(lb):	1042.3	1062.4	1146.6	1121.7
	(kg):	472.8	481.9	520.1	508.8
No. fish (2/24/84)(split)		274560	275058	277242	277134
Fish size (2/24/84)(split)	(g/fish):	1.722	1.752	1.876	1.836
	(fish/lb):	263.4	258.9	241.8	247.0
	(fish/kg):	580.7	570.8	533.0	544.7
Wt. of fish at release (5/8/84)	(lb):	3844.5	3426.7	4712.6	4086.8
	(kg):	1743.8	1554.3	2137.6	1853.7
No. of fish released (5/8/84):		272648	273216	275853	275607
No. of tagged fish released (5/8/84):		80348	80046	80138	81282
Fish size at release	(g/fish):	6.396	5.689	7.749	6.726
	(fish/lb):	70.9	79.7	58.5	67.4
	(fish/kg):	156.3	175.8	129.0	148.7

APPENDIX IV
(Continued)

Ration:		Oregon Pellet Control		Salmon Meal Ration	
Pond:		C-3	C-4	C-5	C-6
Binary code:		7-31/20	7-31/21	7-31/22	7-31/23
Fish length at release (5/8/84) (mm)	(No):	805	834	921	825
	(mean):	83.3	81.7	88.5	85.6
	(S.D.):	7.26	7.01	6.07	6.88
Hematocrit at release (5/8/84)	(%):	34.8	30.6	36.8	36.6
Mortality	(No.):	33609	28643	22997	15530
12/29/83-2/23/84	(%):	5.525	4.683	3.813	2.556
Mortality	(No.):	1912	1842	1389	1527
2/24-5/8/84	(%):	0.696	0.670	0.501	0.551
Feed (wet wt)	(kg):	745.7	776.5	715.5	737.8
12/29/83-2/24/84	(lb):	7644	1712	1577.5	1626.5
Feed (dry wt)	(kg):	542.1	564.8	549.9	566.9
12/29/83-2/24/84	(lb):	1195.1	1245.3	1212.4	1249.8
Feed Protein	(kg):	284.8	297.3	331.1	340.8
12/29/83-2/24/84	(lb):	627.8	655.4	730.0	751.4
Feed fat	(kg):	114.2	119.2	138.4	142.7
12/29/83-2/24/84	(lb):	251.8	262.9	305.2	314.6
Feed (wet wt)	(kg):	1773.5	1619.3	1635.2	1419.7
2/25-5/6/84	(lb):	3910	3570	3605	3130
Feed (dry wt)	(kg):	1278.4	1166.7	1241.0	1077.2
2/25-5/6/84	(lb):	2818.4	2572.1	2736.0	2374.9
Feed protein	(kg):	655.8	599.1	708.2	618.9
2/25-5/6/84	(lb):	1445.7	1320.9	1561.3	1364.4
Feed fat	(kg):	243.3	221.3	299.9	257.5
2/25-5/6/84	(lb):	536.5	488.0	661.1	567.8
Feed (wet wt)	(kg):	2519.2	2395.8	2350.7	2157.5
12/29/83-5/6/84	(lb):	5554	5282	5182.5	4756.5
Feed (dry wt)	(kg):	1802.5	1731.5	1791.0	1644.1
12/29/83-5/6/84	(lb):	4013.5	3817.4	3948.4	3624.7
Feed protein	(kg):	940.5	896.4	1039.3	959.7
12/29/83-5/6/84	(lb):	2073.5	1976.3	2291.3	2115.8
Feed fat	(kg):	357.6	340.6	438.3	400.2
12/29/83-5/6/84	(lb):	788.3	750.9	966.3	882.4

APPENDIX IV
(Continued)

Ration:		Oregon Pellet Control		Salmon Meal Ration	
Pond:		C-3	C-4	C-5	C-6
Binary code:		7-31/20	7-31/21	7-31/22	7-31/23
Fish weight gain	(kg):	774.2	794.9	875.6	873.8
12/29/83-2/23/84	(lb):	1706.9	1752.4	1930.3	1926.5
Fish weight gain	(kg):	1271.0	1072.4	1617.5	1344.9
2/24-5/8/84	(lb):	2802.2	2364.3	3566.0	2965.1
Body composition at release	Rep 1	76.75	77.37	75.53	75.82
% moisture	Rep 2	76.76	77.18	75.43	75.91
	Rep 3	76.52	77.29	75.23	75.94
	Mean	76.68	77.28	75.40	75.89
	S.D.	0.14	0.09	0.15	0.06
Body composition at release:	Rep 1	2.04	2.04	2.00	1.98
% ash wet wt.	Rep 2	2.00	2.03	1.99	1.97
	Rep 3	2.04	2.05	2.00	1.99
	Mean	2.03	2.04	2.00	1.98
	S.D.	0.02	0.01	0.01	0.01
Body composition at release:	Rep 1	8.77	9.01	8.17	8.19
% ash dry wt.	Rep 2	8.60	8.89	8.10	8.18
	Rep 3	8.69	9.03	8.07	8.27
	Mean	8.69	8.98	8.11	8.21
	S.D.	0.08	0.08	0.05	0.05
Body composition at release	Rep 1	6.76	6.29	8.02	7.68
% fat wet wt.	Rep 2	6.86	6.44	8.15	7.74
	Rep 3	7.02	6.34	8.17	7.76
	Mean	6.88	6.36	8.11	7.73
	S.D.	0.13	0.08	0.08	0.04
Body composition at release:	Rep 1	29.07	27.79	32.77	31.80
% fat dry wt.	Rep 2	29.52	28.22	33.17	32.13
	Rep 3	29.90	27.92	32.98	32.25
	Mean	29.50	27.98	32.97	32.06
	S.D.	0.41	0.22	0.20	0.23
Body composition at release:	Rep 1	15.20	15.17	15.15	15.05
% protein wet wt	Rep 2	15.13	15.15	15.18	14.88
	Rep 3	15.21	15.06	15.26	15.15
	Mean	15.18	15.13	15.20	15.03
	S.D.	0.04	0.06	0.06	0.13

APPENDIX IV
(Continued)

Ration:		Oregon Pellet Control		Salmon Meal Ration	
Pond:		C-3	C-4	C-5	C-6
Binary code:		7-31/20	7-31/21	7-31/22	7-31/23
Body composition at release: % protein dry wt	Rep 1	65.38	67.03	61.91	62.24
	Rep 2	65.10	66.39	61.78	61.77
	Rep 3	64.78	66.31	61.61	62.97
	Mean	65.09	66.58	61.77	62.33
	S.D.	0.30	0.39	0.15	0.60
Fish protein gain 12/29/83-5/8/84	(kg):	310.5	282.5	378.9	333.5
	(lb):	684.5	622.8	835.4	735.2
Fish fat gain 12/29/83-5/8/84	(kg):	140.7	118.7	202.2	171.5
	(lb):	310.2	261.8	445.7	378.1
Feed (wet wt)/wt gain 12/29/83-2/24/84		0.9631	0.9769	0.8172	0.8443
Feed (wet wt)/wt gain 2/24 - 5/8/84		1.3953	1.5099	1.0109	1.0556
Feed (wet wt)/wt. gain 12/29/83 - 5/8/84		1.2317	1.2831	0.9429	0.9724
Feed (dry wt)/wt. gain 12/29/83 - 2/24/84		0.7002	0.7106	0.6281	0.6487
Feed (dry wt)/wt. gain 2/24 - 5/8/84		1.0058	1.0879	0.7672	0.8009
Feed (dry wt)/wt. gain 12/29/83 -5/8/84		0.8901	0.9273	0.7184	0.7410
Feed protein/protein gain 12/29/83 - 5/8/84		3.0292	3.1732	2.7427	2.8778
Condition factor: 100,000 x wt (g)/ length (mm)^3		1.1065	1.0432	1.1179	1.0723
Body fat (9.0 kcal/g)/ protein (4.0 kcal/g)		1.0198	0.9458	1.2005	1.1572